The EMPIRE JOURNAL of EXPERIMENTAL AGRICULTURE

VOLUME IV

OXFORD
AT THE CLARENDON PRESS 1936

D-70
77321
Agri

EDITORIAL BOARD

SIR E. J. RUSSELL, Rothamsted Experimental Station, Harpenden (*Chairman*).

SIR R. H. BIFFEN, School of Agriculture, Cambridge.

J. M. CAIE, Dept. of Agriculture for Scotland, Edinburgh.

PROF. F. L. ENGLEDOW, School of Agriculture, Cambridge.

SIR A. D. HALL, John Innes Horticultural Institution, Merton Park, London, S.W. 19.

C. BRYNER JONES, Ministry of Agriculture, Welsh Dept., Aberystwyth.

H. J. PAGE, Agricultural Research Station, Jealott's Hill, Bracknell, Berks.

PROF. J. A. S. WATSON, School of Rural Economy, Oxford.

(*The above constitute the Executive Committee*)

J. M. ADAMS, Dept. of Agriculture, Dublin, I.F.S.

DR. E. S. ARCHIBALD, Central Experimental Farm, Ottawa, Canada.

M. A. BAILEY, Gezira Agricultural Research Service, Wad Medani, Sudan

SIR B. C. BURT, Imperial Council for Agricultural Research, New Delhi, India.

A. H. COCKAYNE, Plant Research Station, Palmerston North, New Zealand.

DR. C. CROWTHER, Harper-Adams Agricultural College, Newport, Salop.

DR. H. J. DENHAM, Institute of Agricultural Engineering, Oxford.

DR. I. ELAZARI-VOLCANI, Agricultural Experiment Station, Rehoboth, Palestine.

SIR G. EVANS, Imperial College of Tropical Agriculture, Trinidad.

SIR R. B. GREIG, Dept. of Agriculture for Scotland, Edinburgh.

PROF. J. A. HANLEY, Armstrong College, Newcastle-on-Tyne.

PROF. J. HENDRICK, Marischal College, Aberdeen.

SIR F. W. KEEBLE, Cedron House, Fowey, Cornwall.

DR. B. A. KEEN, Rothamsted Experimental Station, Harpenden.

W. NOWELL, East African Agricultural Research Station, Amani, Tanganyika.

COL. A. OLVER, Imperial Council for Agricultural Research, New Delhi, India.

SIR J. B. ORR, Rowett Institute, Aberdeen.

C. S. ORWIN, Agricultural Economics Research Institute, Oxford.

DR. I. B. POLE EVANS, Dept. of Agriculture, Pretoria, South Africa.

DR. A. E. V. RICHARDSON, Waite Agric. Research Inst., Glen Osmond, South Australia.

DR. G. SCOTT ROBERTSON, Ministry of Agriculture, Northern Ireland.

PROF. R. G. STAPLEDON, Welsh Plant Breeding Station, Aberystwyth.

F. A. STOCKDALE, The Colonial Office, London.

PROF. R. G. WHITE, University College of North Wales, Bangor.

Secretary and General Editor

DR. E. H. TRIPP, 40 Trewsbury Road, Sydenham, London, S.E. 26.

287633

CONTENTS

Number 13

T. Rigg and H. O. Askew: Further Investigations on Bush-sickness at Glenhope, Nelson, New Zealand. With Plate 1 . 1

D. D. Paterson: The Cropping Qualities of Certain Tropical Fodder Grasses. With Plate 2 6

M. H. French: The Development of Live Stock in Tanganyika Territory. I. Actual and Proportional Weights of the Various Parts of the Body of Zebu Cattle. With Plates 3, 4 . . . 17

S. J. Watson and E. A. Horton: Technique of Digestibility Trials with Sheep and its Application to Rabbits. With Plate 5 25

W. H. Gibson: Fibre-flax Cultivation in the United Kingdom and the Empire 36

Norman M. Ross: Tree-planting in the Semi-arid Area of Canada 47

L. C. Raymond: Pasture Studies VIII. Improvement of Grazing Lands in Eastern Canada. With Plate 6 . . . 51

Rice Williams: The Rate of Loss of Exchangeable Lime from North Welsh Agricultural Soils 61

W. G. Cochran and D. J. Watson: An Experiment on Observer's Bias in the Selection of Shoot-heights . . . 69

G. F. March: The Development of Native Agriculture in the Nuba Mountains Area of Kordofan Province, Anglo-Egyptian Sudan 77

C. G. Hansford: Some Effects of the Development of the Cotton Industry on Native Agriculture in Uganda . . . 81

O. T. Faulkner and J. R. Mackie: The Introduction of Mixed Farming in Northern Nigeria 89

Number 14

A. J. Wakefield: Native Production of Coffee on Kilimanjaro. With Plates 7, 8 97

M. H. French: The Weights of the Carcass and of the Individual Organs in the Body of Cattle in Kenya Colony. With Plate 9 108

Nancy Galpin: The Occurrence of a Britch-poll Fibre-type Array Gradient in the New Zealand Romney Lamb . . 116

A. V. Lyon: Irrigation-development in Australia with special reference to Irrigation-settlements of the State of Victoria. With Plate 10 and Map 129

F. Tattersfield: Fish-poison Plants as Insecticides: A Review of Recent Work 136

A. W. Greenhill: The Effects of Partial Field-drying on the Composition of Freshly Cut Grass 145

E. T. Sykes: Experiments on the Nitrogenous Manuring of Sugar-beet 152

D. M. Bryant: The Incidence of Kemp in the Fleece of Scottish Mountain Blackface Sheep, with special reference to Inheritance. With Plates 11, 12 165

James Anderson: Studies on Reproduction in Cattle. Pt. I. The Periodicity and Duration of Oestrus 186

FEB 15 39

Number 15

JAMES ANDERSON: Studies on Reproduction in Cattle. Pt. II. The Influence of Environmental Factors on Reproduction . 197

H. EVANS: The Root-system of the Sugar-cane. II. Some Typical Root-systems. With Plate 13 208

S. P. AIYAR: The Agriculturally Important Soils of Burma . 221

PAUL A. MURPHY: Some Effects of Drought on Potato Tubers. With Plates 14, 15 230

C. W. B. ARNOLD: Some Aspects of Tobacco Culture in Central Africa 247

L. E. KIRK: Forage-crop Improvement in Western Canada for Dry-land Agriculture 255

LL. IORWERTH JONES: The Feeding-value of Pastures Sown with Different Strains of Grasses and Clovers . . . 263

A. W. GREENHILL: The Yield and Composition of Cut Pasture Herbage at Different Times of the Day . . . 274

S. J. WRIGHT: Mechanization in British Farming . . 283

Number 16

A. C. MASON: Empire Sugar 289

W. B. HAINES and EVAN GUEST: Recent Experiments on Manuring *Hevea* and their Bearing on Estate Practice. With Plate 16 300

H. EVANS: The Root-system of the Sugar-cane. Pt. III. The Early Development of the Root-system of Sugar-cane in Mauritius. With Plate 17 325

B. C. ASTON, R. E. R. GRIMMETT, and F. B. SHORLAND: Pampas Grass (*Cortaderia Selloana* (Schult) Aschers and Graben): A New Supplementary Fodder for Ruminants in New Zealand. With Plates 18, 19 332

F. W. ANDREWS: Investigations on Black-arm Disease of Cotton under Field Conditions. I. The Relation of the Incidence and Spread of Black-arm Disease of Cotton to Cultural Conditions and Rainfall in the Anglo-Egyptian Sudan . . 344

R. CECIL WOOD: Village Waste 357

RUDOLPH D. ANSTEAD: Note 364

R. CECIL WOOD: A Manurial Experiment on Bananas . 365

BRYNMOR THOMAS and B. M. BOYNS: The Composition of Grass Laid up for Winter Keep 368

F. HANLEY and F. TUNNINGTON: Experiments on the Growing of Chicory (for Drying) 379

FEB 17 1936

The EMPIRE JOURNAL of EXPERIMENTAL AGRICULTURE

VOLUME IV No. 13 JANUARY 1936

CONTENTS

T. Rigg and **H. O. Askew**: Further Investigations on Bush-sickness. With Plate 1 1

D. D. Paterson: The Cropping Qualities of Certain Tropical Fodder Grasses. With Plate 2 . . . 6

M. H. French: The Development of Live Stock in Tanganyika Territory. Pt. I. With Plates 3, 4 . 17

S. J. Watson and **E. A. Horton**: Technique of Digestibility Trials with Sheep and its Application to Rabbits. With Plate 5 25

W. H. Gibson: Fibre-Flax Cultivation in the United Kingdom and the Empire 36

N. M. Ross: Tree-planting in the Semi-arid Area of Canada. 47

L. C. Raymond: Improvement of Grazing Lands in Eastern Canada. With Plate 6 51

Rice Williams: The Rate of Loss of Exchangeable Lime from North Welsh Agricultural Soils . . 61

W. G. Cochran and **D. J. Watson**: An Experiment on Observer's Bias in the Selection of Shoot-heights 69

G. F. March: The Development of Native Agriculture in the Nuba Mountains Area of the Sudan 77

C. G. Hansford: Effects of the Development of the Cotton Industry on Native Agriculture in Uganda 81

O. T. Faulkner and **J. R. Mackie**: The Introduction of Mixed Farming in Northern Nigeria . 89

OXFORD

AT THE CLARENDON PRESS: 1936

THE EMPIRE JOURNAL OF EXPERIMENTAL AGRICULTURE

EDITORIAL BOARD

Sir E. J. RUSSELL, Rothamsted Experimental Station, Harpenden (*Chairman*).
Sir R. H. BIFFEN, School of Agriculture, Cambridge.
J. M. CAIE, Dept. of Agriculture for Scotland, Edinburgh.
Prof. F. L. ENGLEDOW, School of Agriculture, Cambridge.
Sir A. D. HALL, John Innes Horticultural Institution, Merton Park, London, S.W. 19.
C. BRYNER JONES, Ministry of Agriculture, Welsh Dept., Aberystwyth.
H. J. PAGE, Agricultural Research Station, Jealott's Hill, Bracknell, Berks.
Prof. J. A. S. WATSON, School of Rural Economy, Oxford.

(*The above constitute the Executive Committee*)

J. M. ADAMS, Dept. of Agriculture, Dublin, I.F.S.
Dr. E. S. ARCHIBALD, Central Experimental Farm, Ottawa, Canada.
M. A. BAILEY, Gezira Agricultural Research Service, Wad Medani, Sudan.
B. C. BURT, Imperial Council for Agricultural Research, New Delhi, India.
A. H. COCKAYNE, Plant Research Station, Palmerston North, New Zealand.
Dr. C. CROWTHER, Harper-Adams Agricultural College, Newport, Salop.
Dr. H. J. DENHAM, Institute of Agricultural Engineering, Oxford.
Dr. I. ELAZARI-VOLCANI, Agricultural Experiment Station, Rehoboth, Palestine.
Sir G. EVANS, Imperial College of Tropical Agriculture, Trinidad.
Sir R. B. GREIG, Dept. of Agriculture for Scotland, Edinburgh.
Prof. J. A. HANLEY, Armstrong College, Newcastle-on-Tyne.
Prof. J. HENDRICK, Marischal College, Aberdeen.
Sir F. W. KEEBLE, Hamels, Boar's Hill, Oxford.
Dr. B. A. KEEN, Rothamsted Experimental Station, Harpenden.
W. NOWELL, East African Agricultural Research Station, Amani, Tanganyika.
Col. A. OLVER, Imperial Council for Agricultural Research, New Delhi, India.
Sir J. B. ORR, Rowett Institute, Aberdeen.
C. S. ORWIN, Agricultural Economics Research Institute, Oxford.
Dr. I. B. POLE EVANS, Dept. of Agriculture, Pretoria, South Africa.
Dr. A. E. V. RICHARDSON, Waite Agric. Research Inst., Glen Osmond, South Australia.
Dr. G. SCOTT ROBERTSON, Ministry of Agriculture, Northern Ireland.
Prof. R. G. STAPLEDON, Welsh Plant Breeding Station, Aberystwyth.
F. A. STOCKDALE, The Colonial Office, London.
Prof. R. G. WHITE, University College of North Wales, Bangor.

Secretary and General Editor
Dr. E. H. TRIPP, 40 Trewsbury Road, Sydenham, London, S.E. 26.

NOTICE TO CONTRIBUTORS

Papers submitted for insertion should be sent to Dr. E. H. Tripp, 40 Trewsbury Road, Sydenham, London, S.E. 26, but authors residing overseas should, where possible, send their papers through the local member of the Editorial Board; they should also name agents in Britain to whom proofs, &c., may be referred.

Authors are asked to submit their papers finished in all details, in typescript with double-line spacing, and with ample margins. Illustrations should if possible be drawn, about twice the size of the finished block, on smooth, white Bristol board in Indian ink, with marginal lettering inserted in pencil. Their order and approximate position in the text should be marked. The length of papers, including tabular matter and illustrations, should not exceed the equivalent of 5,000 words. An allowance at the rate of ten shillings per sheet of sixteen pages is made for alterations in the proof (printers' errors excepted), and contributors will be responsible for any excess.

The address to which proofs are to be sent should be written on the paper and, when returning corrected proofs to Dr. Tripp, authors should state whether they desire to purchase additional offprints. Twenty-five offprints are allowed free of charge.

The Journal is published four times yearly by Mr. Humphrey Milford, Oxford University Press, Amen House, Warwick Square, London, E.C. 4, to whom subscriptions and all communications, other than editorial, should be addressed.

ANNUAL SUBSCRIPTION 20s. POST FREE; SINGLE NUMBERS 7s. 6d. net.

FURTHER INVESTIGATIONS ON BUSH-SICKNESS AT GLENHOPE, NELSON, NEW ZEALAND

T. RIGG AND H. O. ASKEW

(Cawthron Institute, Nelson, N.Z.)

WITH PLATE I

Introduction.—In a previous publication [1] attention was drawn to the strikingly beneficial results that were obtained by the use of a soil drench in the prevention of bush-sickness at Glenhope, Nelson. The work reported there was continued for a longer period, with the result that the sheep which received drench-treatments of ferric ammonium citrate or of Parapara limonite, or which remained without treatment, went off in health quickly in the following spring so that by midsummer not one of the nineteen animals originally in these groups remained alive.[1] On the other hand, the animals receiving the Nelson-soil drench continued in perfect condition and by April 14 of the second season showed an average live-weight of 141 lb. These sheep were held on the same bush-sick pasture until the following October (1934), having been two years on the soil drench. All the animals were perfectly healthy and in very good condition.

In view of the results obtained by Filmer and Underwood [2] in Western Australia with dilute-acid extracts of limonite, even in the iron-free condition, for the treatment of a disease showing some similarities to bush-sickness, it was thought desirable to see whether the beneficial constituents of Nelson soil were readily soluble in dilute hydrochloric acid. A drench was accordingly prepared and used during the 1934–5 season.

Experimental

Five groups of six hoggets each, introduced from healthy country, were grazed on the bush-sick pasture at Glenhope. The groups represented the following treatments:

1. Control.
2. Nelson soil as used in previous seasons.
3. Acid extract of Nelson soil.
4. Extracted Nelson soil.
5. Wakatu soil.

This last treatment was introduced in order to test another Nelson-soil type which, so far as is known, is healthy to stock. Drenching twice weekly with equivalent amounts of soil was carried out, commencing on October 12, 1934.

The extract from the Nelson soil was obtained by heating one part of soil with 10 parts of N/8 hydrochloric acid; after filtering, the soil was washed a few times with water and then dried for use as one of the above treatments (extracted soil). The liquid extract was evaporated to a volume convenient for drenching purposes; a volume of liquid corresponding to the same amount of soil employed in the other groups was used. It must

[1] Unpublished results.

be emphasized that this process of extraction was not very rigorous, so that all of the beneficial constituents may not have been removed from the soil.

The animals were weighed and arranged in groups on October 12, 1934, after being on the bush-sick pasture for a week or two to settle down to their new surroundings. The first drench was administered to the respective groups on the same date.

Results

In Table 1, and in the accompanying graph (Fig. 1), are shown the average live-weights of the sheep in the various groups throughout the

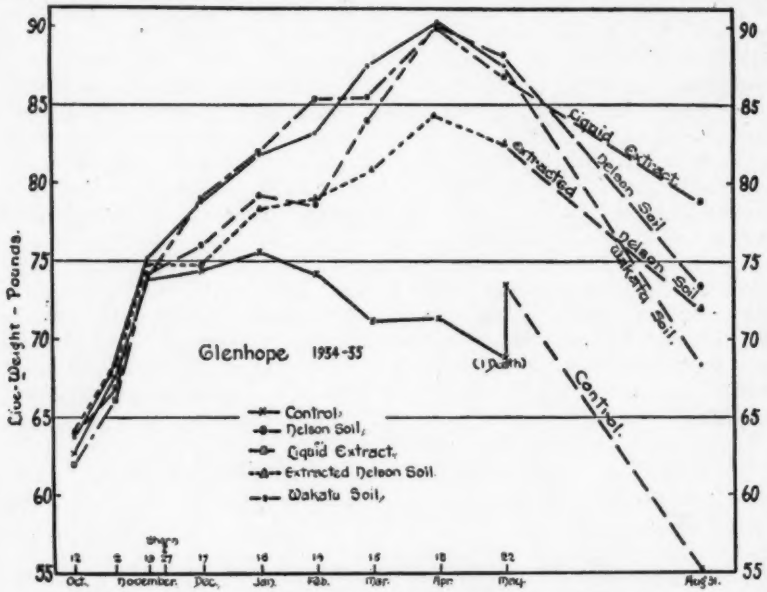


Fig. 1. Average live-weights of sheep in groups at Glenhope.

period of the experiments. There is a long period from May 22, 1935, to August 31, 1935, during which weight records were not taken; field notes covering the condition of the sheep for this intervening period are, however, available.

The records indicate that all the groups receiving drenches increased steadily in weight until the middle of April; but of these groups the extracted-soil group was the least satisfactory. All the animals were, however, healthy. The curve for the control group reached its maximum in the middle of January with an average live-weight at this period of 75·6 lb., whereas the acid-extract group, for example, at this time had an average weight of 82·0 lb. By the middle of January at least one sheep in the control was showing signs of bush-sickness. As the season progressed

TABLE 1. *Average Live-weight in Pounds of Sheep receiving Drench-treatment, Glenhope 1934–5*

Treatment	*Oct. 12, 1934*	*Nov. 2, 1934*	*Nov. 19, 1934*	*Dec. 17, 1934*	*Jan. 16, 1935*	*Feb. 14, 1935*	*Mar. 15, 1935*	*Apr. 18, 1935*	*May 22, 1935*	*Aug. 31, 1935*
Control .	62·7	67·6	73·8	74·4	75·6	74·2	71·2	71·4	68·8	55·2
Nelson soil .	63·9	66·8	74·2	76·0	79·2	78·6	84·0	90·2	88·2	73·4
Acid extract of Nelson soil .	62·0	66·2	74·0	79·0	82·0	85·4	85·5	90·0	86·8	78·8
Extracted Nelson soil .	63·9	68·3	74·8	74·8	78·3	79·0	80·8	84·3	82·5	72·0
Wakatu soil .	63·7	68·3	75·2	78·8	81·8	83·2	87·5	90·3	87·5	68·4

NOTE: Sheep were shorn on Nov. 27, 1934.

more of the animals of the control group became affected with bush-sickness, whereas until the end of June the animals of the other groups remained healthy. The loss in weight shown after April is due mainly to the onset of cold weather and cessation of active pasture-growth. In the late autumn and winter the sheep in the control group became badly affected with bush-sickness; this is shown plainly in the graph by the rapid loss in weight. The break in the curve of the control group at May 22 is due to a recalculation of the live-weight of the group following the death of one animal about June 1.

All of the other groups show considerable losses in weight, the losses being least in the cases of the Nelson-soil and the acid-extract groups; of these two the acid extract was the better group. On August 31, 1935, all the animals in these two groups were healthy and in very fair condition considering the inclement weather to which they had been exposed. In the extracted-soil and Wakatu-soil groups, however, cases of bush-sickness appeared early in July, and by August 31 several animals of each group were badly affected, whilst others showed symptoms of approaching sickness.

Discussion

The live-weight data presented above show that very definite differences occur in the ability of the several drench-treatments to prevent the onset of bush-sickness. Whereas the Nelson-soil and the acid extract have maintained the animals in good health, the other two soil drenches (extracted soil and Wakatu soil) have not been able to keep the animals healthy. It is important to note that the last two groups appeared to give satisfactory results until the late autumn, and that bush-sickness appeared in the winter. The explanation of this may be that the quantity of the active constituent, or constituents, present in these soils, although beneficial, was not sufficient to maintain the sheep in health over an extended period in which, owing to cold weather and shortage of feed, the sheep were subjected to extra strain.

In the case of the Wakatu soil it might well be asked: why do sheep remain healthy when grazed on pastures established on the soil type whilst in drench form the same soil has proved only partly successful at Glenhope in preventing the incidence of bush-sickness? This may be

explained by the fact that sheep grazing Wakatu pastures actually ingest much more soil than was supplied to the sheep at Glenhope in drench form. The larger quantity of soil, combined with a probable higher intake by Wakatu pastures of the active constituent, or constituents, would thus account for the healthy conditions of sheep on Wakatu farms.

The photographs, taken on September 4, 1935, show that the sheep receiving Wakatu soil (Fig. 2 (*b*), Pl. 1) are by no means so good as the sheep receiving the acid extract (Fig. 2 (*a*), Pl. 1), they having gained only an average of 4 lb. over their weight of October 12, as against an average gain of 17 lb. shown by the sheep receiving the acid extract. The control group (Fig. 2 (*c*), Pl. 1), are in very poor condition, and are 5 lb. per head below their weight when the experiment began.

The Nelson-soil and acid-extract groups remain for consideration. It will have been noticed that at the end of the season the Nelson-soil group is not much heavier than the extracted-soil group, and that this group was only 9 lb. heavier per head than at the beginning of the season. The average weight of the Nelson-soil group was reduced by the presence of a thin, constitutionally weaker animal, which, however, does not show any signs of bush-sickness. All the animals in the above two groups are quite healthy and carry good bright wool, in contrast with the harsh, dry, and lustreless wool of the control group.

The results of this season's work indicate definitely that the acid extract of Nelson soil has given very good results, in fact, the best result of all the treatments. This suggests that the beneficial properties of Nelson soil are connected with a constituent, or constituents, soluble in dilute hydrochloric acid. This suggestion is confirmed by the inability of the extracted soil to maintain sheep in health over an extended period.

Analysis of the acid extract shows that the sheep would receive a supplement of 50 mgm. of iron (Fe) per week by this drench-treatment. A supplement of only 7 mgm. of iron per day in the diet of the sheep does not appear to explain the beneficial results that have been obtained by the use of this acid extract of Nelson soil. A consideration of the iron-intake of sheep grazing Glenhope pastures shows that, on a basis of 0·006 per cent. of iron (Fe) in the pastures, the sheep would obtain not less than 60 mgm. of iron (Fe) per day, without including additional iron obtained by ingesting Glenhope soil. A supplement of 7 mgm. of iron per day is such a small addition to the normal iron-intake of Glenhope sheep that it seems highly improbable that the beneficial results obtained by administering the acid soil-extract are due solely or mainly to this increment in the iron supply of the sheep.

The results secured with the Wakatu soil show clearly that apparently healthy sheep soils, when used in drench form on Glenhope sheep, vary in their effectiveness in combating bush-sickness. The most probable explanation of the beneficial properties of the acid extract of Nelson soil is that some constituent, or constituents, other than iron, are mainly responsible for the good results which have been obtained. The Wakatu soil does not appear to possess a high supply of the beneficial constituent, or constituents.

Fig. 2 (*a*). Sheep receiving Acid Extract of Nelson soil. Sept. 4, 1935

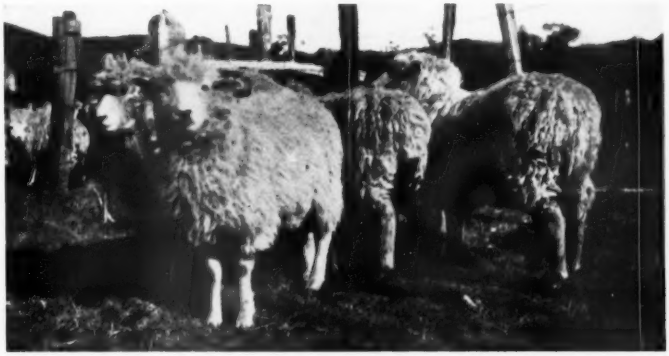


Fig. 2 (*b*). Sheep receiving Wakatu soil. Sept. 4, 1935

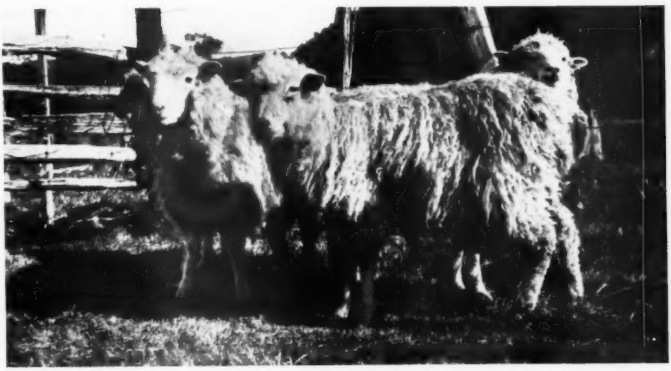


Fig. 2 (*c*). Control group. Sept. 4, 1935

Examination of the acid extract of Nelson soil shows the presence of a number of metallic elements, for example, cobalt, nickel, copper, &c. In view of the amazing results obtained by Australian workers in connexion with 'coast disease' [3] and with enzootic marasmus in Western Australia [4] by the use of minute quantities of cobalt, it does appear probable that one or more of these trace elements may be concerned in the beneficial effects noted in the case of Glenhope sheep treated with an acid extract of Nelson soil.

This possibility is being further explored during the coming season. An iron-free extract of Nelson soil will be tested on one group of sheep, and other tests will be made of some of the trace metals which have already been identified in the acid extract of Nelson soil.

Summary

1. The good results obtained with a drench of Nelson soil for sheep on a bush-sick pasture have been confirmed.

2. An acid extract of Nelson soil used in the liquid condition has given very good results in the prevention of bush-sickness.

3. The residual soil after extraction with acid was not found to prevent the onset of bush-sickness.

4. A second soil from the Nelson district was not found satisfactory in preventing the onset of bush-sickness.

5. The iron-content of the acid extract of Nelson soil did not appear to be the only factor in the control of bush-sickness at Glenhope. Other elements present in small quantities are probably the beneficial constituents in Nelson soil and in the liquid extract of Nelson soil.

Acknowledgements

Special thanks are due to Mr. N. McConochie, who has carefully attended to the experimental sheep.

This work forms part of that being carried out under the Pasture Research Scheme at the Cawthron Institute, towards which the New Zealand Department of Scientific and Industrial Research has given financial assistance.

REFERENCES

1. T. Rigg and H. O. Askew, Emp. J. Expt. Agric., 1934, **2**, 1.
2. J. F. Filmer and E. J. Underwood, Austral. Vet. J., 1934, **10**, 83.
3. H. R. Marston, J. Coun. Sci. & Ind. Res. (Austral.), 1935, **8**, 111; E. W. Lines, ibid., p. 117.
4. E. J. Underwood and J. F. Filmer, Austral. Vet. J., 1935, **11**, 84.

(*Received November 6, 1935*)

THE CROPPING QUALITIES OF CERTAIN TROPICAL FODDER GRASSES

D. D. PATERSON

(Imperial College of Tropical Agriculture, Trinidad, B.W.I.)

WITH PLATE 2

The Experiment

IN two earlier publications [1, 2] the writer has emphasized the need and importance of scientific research on tropical fodder crops. The available information on this aspect of tropical agriculture is particularly meagre, and in consequence the following account of a small field trial of six varieties of fodder grass grown in Trinidad has been prepared, as it does add a little to our knowledge of a subject that has been rather neglected in the past. The experiment consisted essentially of observation plots on which six fodder grasses were planted and subjected to various cultural treatments. The total area involved was small, and the layout did not permit a valid statistical interpretation of the yield data. In place of this, accurate field notes were kept week by week recording the differential behaviour of the grasses under the various treatment series. The results, within the limits of a single experiment, were both striking and conclusive, and are summarized in the following pages.

The varieties included were:

Elephant Grass (*Pennisetum purpureum*)
Guatemala Grass (*Tripsacum laxum*)
Guinea Grass (*Panicum maximum*)
Para Grass (*Panicum barbinode*)
Uba Cane (*Saccharum sinense*, var. *Uba*)
Coimbatore Cane (*Saccharum sinense*, var. *Co. 213*).

Accurate botanical descriptions of these species may be found in the references cited [3–6]. It will suffice here to state that they are all well-known perennial grasses which thrive under the climatic and soil conditions prevailing in the humid tropics, where they are being cultivated on an increasing scale as fodder crops. They are generally utilized on the soiling system, but they may also occur naturally in the herbage of waste and pasture lands, where they may be grazed. Planting of the experimental area took place in May 1933, propagation being obtained from root-division of old stools. All species were given three months in which to get established and were first sown on August 9, when the experimental period commenced. Records were taken over the ensuing twelve months.

During the establishment-period two inter-cultivations with the horse-hoe were carried out to keep down weeds, and the blanks were twice supplied. At the beginning of the experiment proper in August, the stand on all plots was approximately 100 per cent. Before planting, farmyard manure at the rate of 15 tons per acre was broadcast over the whole area and ploughed in. During the experiment light dressings of a complete organic fertilizer were applied at three-monthly intervals.

This compound manure, of which blood-meal was the chief ingredient, contained approximately N 11, P_2O_5 2, and K_2O 10 per cent.; it was broadcast between the rows at the rate of 2 cwt. per acre, and lightly hoed into the surface-soil. The soil on the experimental site has been described [7] as a sandy loam of medium-low nutrient status, and periodic applications of manure are essential in order to maintain fertility and counteract the effects of leaching and continuous cropping.

The area under each fodder grass was divided into small sub-plots on which the following treatments were located in all combinations:

Treatment	*Descriptions*
Spacing	2 × 1½ ft. and 3 × 2 ft.
Cutting-rotations . . .	A. Cut every 45 days or 8 times per year
	B. „ 90 „ 4 „ „
	C. „ 120 „ 3 „ „
	D. „ 180 „ 2 „ „
Height of cutting . . .	Shaved, i.e. cut at ground-level
	Normal, „ „ 4–6 in. above ground-level
	High, „ „ 9–12 in. „ „

Propagation.—Varietal differences as regards number of successes and growth-increment were quickly apparent. The Elephant Grass sprouted the best, the majority of the sets taking root and giving a good leaf-growth in a comparatively short period. The Uba Cane and the Guatemala Grasses were decidedly the poorest, needed the greatest number of supplies, and showed the lowest productivity. The other three fodders —the Co. 213 Cane, Para Grass, and Guinea Grass—were not quite up to the standard of the Elephant Grass. The Coimbatore Cane was superior to the Uba. The following yields of green herbage per 1/40th acre plot, as recorded at the preliminary mowing, reflect the comparative growth-rate of the six fodders during the establishment-period:

Elephant Grass . .	617 lb.	Co. 213 Cane . .	351 lb.
Guinea Grass . .	509 „	Guatemala Grass . .	121 „
Para Grass . . .	473 „	Uba Cane . . .	78 „

In the original planting, single-tiller root-sections were used throughout. For the supplies larger sets consisting of 2–3 tillers-cum-roots were tried and gave a much greater percentage of successes, and also improved early productivity. These supplies were put in some three weeks after planting, yet, at the first harvest, it was impossible to distinguish any difference in size between them and the older stools. The later sets, which were planted after the rainy season had effectively set in, were undoubtedly favoured. This is not surprising, as many tropical grasses, e.g. Para and Elephant Grass, are naturally adapted to thrive best under very wet semi-swamp conditions.

Regeneration.—It has already been noted [2] that the ratoon-crop can be produced in two ways, by terminal or bud-development. The interaction between the cutting technique and the regeneration habit of the plant is looked upon as particularly important in view of its influence on yield, on plant-survival, and even on the nutritive quality of the herbage. In the tropics there is a much greater tendency for plants to shoot than

in temperate regions, and under certain conditions this might give rise to relatively poor tillering. The explanation is, presumably, that the rapidly developing main axis utilizes the majority of the nutritive elements absorbed by the roots, and, in addition, may even carry up with it many of the potential buds that might otherwise have given rise to new tillers.

As elongation of the original axis can occur only when the terminal buds are left on the stool at harvest, there are two factors which largely determine the method of regeneration that will be adopted by the plant, (*a*) the height at which the bud is located at harvest, and (*b*) the height at which mowing occurs. Now the former factor depends on the length of the main axis, and this in turn on its age, or in other words, on the number of days from the previous harvest. In the 'frequently-cut' series, the produce never grows beyond the leafy stage, the culms are short and the growing tip of each shoot is relatively close to the ground. Under these circumstances the terminal bud is not likely to be reaped, and terminal sprouting generally results. On the other hand, in the long cutting-rotations the culms are well developed, mowing almost certainly occurs below the level of the growing point, and bud-sprouting must follow. These features were most marked in the case of Guinea and Guatemala Grass and least evident in the Para Grass, whose tangled habit of growth and faculty of rooting wherever the nodes come in contact with the ground made it impossible to determine accurately how the ratoons were produced. In the case of the two canes in Series D—the 6-month rotation—the presence of a fair percentage of terminal sprouts was at first rather surprising. They were generally located round the periphery of each stool, and were traced to young immature tillers which had been harvested along with the more mature canes on the rest of the stool. A combination of both types of sprouting is desirable to ensure the production of large virile stools, and on the average this duplicate regeneration does occur when a 3–4-month rotation is adopted.

It should now be readily understood why the height of mowing is of such importance in determining regeneration-habit. The shaving of the stools to ground-level must cause in every stool, not excluding those of Series A, bud-sprouting only, whereas cutting at one foot high tends to encourage terminal development, as then, except in the case of semi-mature herbage, removal of the terminal buds will rarely occur. Furthermore, as terminal development is associated with rapid ratooning, quicker growth might be expected on the 'high-cut' plots than on those cut low or shaved. This was demonstrated conclusively in the experiment. Even at the succeeding harvest there was a definite height-gradation in the produce of any one cutting series, according to the level at which the stools had been reaped. Height-measurements were taken before every harvest of 10 stools selected at random from each treatment. The height recorded for each stool represented the average of the five longest tillers. The mean values for the season are recorded in Table 1.

Owing to the growth-peculiarities of the Para and Elephant Grass it was not possible to obtain comparable data for these two fodders. The same marked stepped effect in the height of the produce from the 'high-

TABLE 1. *The Mean Height in Feet of the Herbage in each Treatment*

	Co. 213			*Uba Cane*			*Guinea Grass*			*Guatemala Grass*		
Series	*High cut* (H)	*Medium cut* (M)	*Shaved* (S)	H	M	S	H	M	S	H	M	S
A	4·54	3·77	2·72	4·32	3·64	1·71	3·75	2·37	1·83	3·55	3·01	2·05
B	6·60	5·66	4·50	6·30	5·58	4·34	4·20	4·04	3·64	4·70	4·16	3·44
C	9·75	8·60	7·75	9·25	8·30	7·75	6·10	5·75	5·25	6·50	5·30	5·00
D	9·75	9·10	8·60	9·10	8·50	7·75	6·00	5·25	4·60	8·00	7·10	6·20
Means . .	*7·66*	*6·78*	*5·89*	*7·24*	*6·50*	*5·39*	*5·01*	*4·35*	*3·83*	*5·69*	*4·89*	*4·17*
Means expressed as a percentage of the 'high-cut' values .	100	88	77	100	90	74	100	87	76	100	86	73

cut' to the shaved plots was nevertheless present. This difference in level at harvest was too large to be explained by the initial few inches difference in the stools as a result of the cutting technique adopted, and it must be assumed that high cutting up to one foot leads to a ratoon-crop that will be ready for harvest relatively quickly. That this quicker maturing does actually occur is further attested by the fact that the flowering heads of the Guinea Grass always made their appearance first of all in the plots that had been mown high, and were rarely found on those that had been shaved. By altering the height of cutting in accordance with the number of days between harvests and the particular variety of grass, it is therefore possible to predetermine the system of regeneration that will be adopted by the ratoon-crop and approach the ideal in which rapid sprouting is coupled with multiple tillering. Other factors, in particular soil type and quantity of available nutrient, will also influence results in any particular locality. From the practical aspect it is possible that, in the final selection of method, high-cutting up to one foot might be slightly favoured, as this system avoids the severing of the hard fibrous bases of the culms and is easier on the labourer. It may slightly decrease the total weight of the cut fodder, but this should be more than compensated by the increase in nutritive quality of the produce as a result of the more leafy character of the herbage removed.

Stool survival.—As a test of the effects of the various treatments on the general vigour of the plant, the number of stools surviving on each sub-plot after every harvest was recorded. There did not appear to be any distinct seasonal trend in the stool mortality, and the final count taken in August, 1934, has been used as an index of the response of the plant to any particular treatment (Table 2).

Although an analysis of variance has been carried out on these figures, it is fully realized that the layout and the data are not such as to provide conclusive evidence regarding differences in mortality between the various treatments. The following results, although based on significant differences between treatment totals, are therefore tentative findings requiring further proof. The wider spacing has reduced the stool mortality. The survival percentage is highest in the Guinea Grass and lowest in the Uba Cane. The height of cutting and the rotation adopted have

TABLE 2. *Final Stool Population per Plot on August 20, 1934*

(based on a possible maximum of 24)

		Wide Spacing				*Close Spacing*				
		Co. 213	*Uba Cane*	*Guinea Grass*	*Guatemala Grass*	*Co. 213*	*Uba Cane*	*Guinea Grass*	*Guatemala Grass*	*Totals*
Series A	High-cut	23	24	24	24	24	24	24	24	191
	Normal	23	19	24	21	24	24	24	20	179
	Shaved	21	3	24	13	20	10	16	4	111
Series B	High-cut	23	24	24	24	23	24	24	24	190
	Normal	24	23	24	23	23	21	24	22	184
	Shaved	21	19	24	19	22	14	19	17	155
Series C	High-cut	24	24	24	23	19	22	24	24	184
	Normal	23	24	24	24	24	18	23	24	184
	Shaved	24	19	24	24	21	16	19	16	163
Series D	High-cut	24	24	24	24	22	22	23	24	187
	Normal	24	24	24	24	24	22	22	24	188
	Shaved	19	19	24	24	19	16	20	19	160
Totals		273	246	288	267	265	233	262	242	2,076
				1,074				1,002		

Variety Totals

Co. 213	538	Guinea Grass	550
Uba	479	Guatemala Grass	509

had a marked difference on the percentage survival. Differences greater than 22·0 between the totals given in the final column are statistically significant. This proves that shaving combined with frequent cutting produces the maximum mortality in the stools. Furthermore, shaving for each of the rotations separately has caused a definite lowering in the percentage survival. The explanation lies in the nature of the stool developed under the frequent-cutting rotation, as in Series A; it is definitely inferior in size, in number of tillers, and in root-development to those of the longer rotations [2]. This general effect was accentuated in the case of the shaved stools, which were markedly smaller than the adjacent high-cut stools of the same series. These conclusions are based on records obtained from four varieties of tropical fodder, and illustrate a general rule which has been shown to apply also to pastures in England [8, 9]. Cutting too frequently or mowing too closely impairs the general vigour of the plant, and results in a small underdeveloped stool with a poor root-system.

Hardiness.—In selecting a perennial fodder, it is not only the potential yield of nutriment per acre that must be considered, but also the ability of the crop to smother weed-growth. The varieties under test showed considerable differences in this direction. The Para and Guatemala Grasses were undoubtedly the best, and effectively smothered all extraneous vegetation. The Guinea Grass and Co. 213 Cane were both good. The Uba Cane and Elephant Grass permitted much the heaviest growth of weeds. As in earlier experiments [2], the occurrence of weeds in all the varieties was greatest in plots of Series A and least in those of Series D, where a long cutting-rotation was used. It was evident too that plots which were shaved were more prone to weed-infestation than those in which the stools were cut somewhat higher. This is to be expected, as

shaving results in slow ratooning, and ultimately in a certain mortality in the stools. The closer spacing, $2 \times 1\frac{1}{2}$ ft., tended to decrease the weed-population, particularly with the less vigorous fodders. The difference between the weeds on the two spacings was not considered sufficiently great to warrant the extra expense involved in close-planting: $3 \times 1\frac{1}{2}$ ft., or 3×2 ft., appears to be a satisfactory planting-distance for the average tropical fodder grass cropped on any reasonable cutting-rotation.

The only serious pest recorded was the *Helminthosporium* fungus on the Elephant Grass, as already noted [1, 2]. Under normal conditions Elephant Grass has all the characters essential to a good perennial fodder crop, including aggressiveness, persistence, high productivity and nutritive quality, and it has recently been introduced to several new areas with marked success. Except for its susceptibility to this particular fungus, Elephant Grass has therefore many excellent qualities, and an attempt is being made to produce a resistant strain.

Flowering in a perennial fodder grass is a feature that is not generally desirable, as it is usually accompanied by a loss in herbage-productivity and in nutritive quality. Two of the grasses showed a decided tendency to run into flower, namely, Guinea Grass and Para Grass. In Series B, C, and D, ranging from 3 to 6 months between cuts, flowers had always made their appearance before reaping occurred. At some seasons of the year, in Series D a second flush had time to develop before harvest became due. Even in Series A, with only $6\frac{1}{2}$ weeks between ratoons, some of the stools produced flower-heads. The fact that the inflorescences always appeared first in the high-cut stools has already been commented upon. Of the two flowering varieties, the undesirable change in growth-habit is particularly marked with Guinea Grass, whose inflorescence-panicle is borne on a long fibrous stalk, and whose foliage turns yellowish and apparently suffers a loss in nutritive quality. Flowering in the Para Grass is probably just as frequent, but it is not accompanied by any marked alteration in the vegetative growth, and the leaves and stems remain green and succulent. This susceptibility of the Guinea Grass to seed-production makes it definitely inferior to the other varieties as a fodder crop for Trinidad. It is grown by some farmers to provide roughage for horses, for whom a dry type of fodder is preferable.

The exceptionally severe dry spell of 1934 provided an excellent test of the respective capacities of the grasses to withstand drought. From January to August, 1934, the total rainfall amounted to 9·55 in., representing only 28 per cent. of the normal. The herbage-yields in consequence were reduced to about 25 per cent. of that of the wet season. The percentage mortality due to drought alone was apparently nil, so that it can be stated that all the grasses are hardy enough to withstand successfully dry-weather conditions, which, for Trinidad, were abnormally prolonged. The varieties showed considerable differences in their reactions to the dry season. The two canes suffered least and continued to yield a reasonable bulk of green fodder throughout the dry months. The Guatemala and Guinea Grasses turned very dry and yellow, and the leaves tended to roll up longitudinally into narrow spills. The Elephant Grass practically stopped growth as a result of combined fungal infection

and drought. The Para Grass altered its habit of growth and limited its development to the production of long prostrate runners, and as a result the yield of edible fodder was negligible.

Composition.—In order to provide material for chemical analysis, representative samples of the produce from the first harvest of each of the main treatment series were collected. Five stools were selected at random from each plot harvested, and sampled as described in [2]. The following figures, showing the nitrogen percentages from the duplicate samples of Series A, were recorded to ascertain whether or not the sampling technique was sufficiently accurate to give produce uniform in character and truly representative of the nutritional value of the series from which it had been obtained.

Series A. Harvested

Percentage Nitrogen in Dry Matter

	Elephant Grass	*Uba Cane*	*Guatemala Grass*	*Guinea Grass*	*Co. 213 Cane*	*Para Grass*
1st Sample	1·29	1·12	1·07	1·26	1·08	1·41
2nd Sample	1·28	1·11	1·05	1·14	1·04	1·49
Means .	*1·285*	*1·115*	*1·060*	*1·200*	*1·060*	*1·450*

Analysis of variance of these nitrogen percentages demonstrates that the variation within samples is negligible in comparison with that between samples, and that the maximum difference between any pair of duplicate readings is statistically non-significant. A difference between varietal means greater than 0·11 is significant, proving that there is a considerable and real difference in the nitrogen-content of the six varieties. Para Grass is decidedly the best, but Uba, Co. 213 Cane, and Guatemala Grass are relatively low in nitrogen. In general, a difference exceeding some 9 per cent. of the mean values quoted may be taken as real on a probability of 0·05. The results of the chemical analysis are summarized in Table 3.

TABLE 3. *Dry-Matter and Protein-Percentages for the Different Varieties and Cutting-Rotations*

Fodder	*Percentage Dry Matter*				*Variety Mean*	*Percentage Crude Protein in Dry Matter*				*Variety Mean*
	A	*B*	*C*	*D*		*A*	*B*	*C*	*D*	
Elephant Grass .	13·38	21·53	24·35	23·25	*20·65*	9·61	5·93	6·06	4·87	*6·62*
Guatemala Grass .	16·40	16·45	16·95	22·82	*18·15*	8·12	5·74	3·88	3·31	*5·26*
Uba Cane . .	14·15	16·64	18·46	24·75	*18·50*	7·56	4·25	4·37	2·25	*4·61*
Co. 213 . . .	17·69	15·46	19·87	26·45	*19·87*	7·44	5·24	4·18	2·75	*4·90*
Guinea Grass . .	16·16	19·37	24·33	31·85	*22·93*	8·37	5·43	5·87	3·75	*5·85*
Para Grass . .	18·05	17·42	22·08	17·15	*18·68*	11·08	6·87	6·65	4·00	*7·15*
Rotation mean	*15·97*	*17·81*	*21·01*	*24·38*		*8·70*	*5·58*	*5·17*	*3·49*	

These figures indicate, as is to be expected, a marked progressive increase in dry-matter percentage and decrease in crude-protein percentage from Series A to D. The Guinea Grass is a relatively dry type of fodder and for this reason is often preferred for equines. In protein-

percentage, if a difference greater than 9 per cent. of the mean value is taken as significant, the Para Grass is decidedly the best, followed closely by Elephant Grass. The mean protein-percentages of the two canes are very low, in part due to the rapid drop in nitrogen-content in Series D as a result of the development of the sugar-canes. The high nutritive value of Para Grass is a fact that is already acknowledged by the farming community. Dairymen in the locality even maintain that changing the ration of their milch cows from other roughages to Para Grass increases both the milk-yield and the butter-fat percentage. Unfortunately, this particular fodder is an obnoxious weed in arable land, and it is for this reason that it has not been more widely cultivated, but is generally limited to localities utilized solely for pasturage. Some authorities [4] state that the nodes can pass unharmed through the digestive tract of animals and ultimately under suitable conditions begin to sprout. This does not appear to be true of cattle in the tropics, as shown by the following experiment. The dung from working oxen fed on Para Grass was collected once a day for a fortnight and carefully elutriated with water over a fine sieve. The solid material remaining on the sieve was examined, and in no case was there any sign of undigested knots or seeds of the Para Grass. To make quite certain, the collected solids were then sown in semi-sterilized soil contained in nursery boxes, and every effort was made to try and induce sprouting of the Para Grass, but without success. The fallacy that this grass can pass undigested through healthy stock has probably arisen from the fact that in feeding, a portion of the fodder falls to the floor of the byre and gets swept up with the dung. It is certain that under such circumstances the Para Grass can survive in a manure heap for long periods, and ultimately begin to grow again when the manure is applied to arable land. Some simple experiments in the composting of Para Grass proved this statement, and indicated that the key to the effective decomposition of this grass lies in chaffing. A comparative trial was started in which the capabilities of decomposition of the following four types of basal material were tested:

(1) Young chaffed Para Grass
(2) Old chaffed Para Grass
(3) Young unchaffed Para Grass
(4) Old unchaffed Para Grass

In each case the material was thoroughly soaked in a mixture of water, urine, and cow-dung, was given a light dressing of lime, ammonium sulphate, and superphosphate in the proportions of 4 : 3 : 2 [10] and made up into a compost heap 15 ft. long by 5 ft. wide at base, and 5 ft. high. The amount of humification resulting is fairly accurately reflected in the weekly temperature chart recorded overleaf:

The heaps were opened at the end of ten weeks, and the decomposition in both chaffed heaps was satisfactory, being a stage more advanced in the young material than in the old. Subsidence in these heaps was very much greater than in the unchaffed produce, which was practically unaltered, and gave a fair percentage of sprouts on being planted in nursery beds. Old runners were obviously more resistant to rotting than the young fresh shoots.

Temperature in °C. at Centre of Compost Heap

Period	Chaffed		Unchaffed	
	Young Shoots	Old Shoots	Young Shoots	Old Shoots
	I	II	III	IV
7th day . .	58	55	33	30
14th day . .	53	51	33	30
21st day . .	45	40	31	30
28th day . .	42	36	30	29
49th day . .	36	32	30	29

A certain amount of sprouting occurred on the outside of all the heaps; this was thickest in the early stages and in the unchaffed produce; the number of surface sprouts surviving at the time of opening the heaps was relatively small. Thus, provided certain precautions are taken, Para Grass can be thoroughly decomposed by the ordinary technique used for making activated composts [10, 11, 12]. If the heaps are turned over a couple of times during the manufacture to ensure that the surface-layer is also fully rotted, there need be no risk of sowing Para Grass on to arable land when the dung from the byre goes out to the field in the form of activated compost. Experiments have now been started to ascertain whether this grass can be as effectively treated by the ordinary system of making farmyard manure in the cattle-pen.

This question has been discussed at some length as, provided the danger of spreading this grass among arable crops is eliminated, it appears to be a particularly promising fodder. One way of effectively avoiding this dissemination risk would be to inaugurate a system of controlled rotational grazing instead of using the Para Grass for soiling. As it has been shown that there is no danger of spreading the Para Grass in the dung, and as carting the cut grass from one part of the land to the next would be eliminated, the field of Para Grass could be successfully isolated from the rest of the farm. The danger of spreading the grass by other means is reckoned to be slight. The grazing practice would be along the lines recommended by Wilsie and Takahashi for Elephant Grass [13] whereby the grazing of the crop is permitted only when the grass has reached the stage of development at which it would normally be cut for soilage. The stock is confined to one small section for a few days at a time and then moved on to the next, thereby preventing the trampling from having any permanent ill-effect on the stools, and yet ensuring that most of the herbage is eaten so as to encourage ratooning. Judging from its growth-habit, Para Grass should be even better able than Elephant Grass to thrive under a grazing treatment. Pasturing is, of course, only practicable with dairy or beef animals, and the soiling system would have to be followed for working oxen.

Discussion

Of the six grasses tested, the Para Grass is outstanding as, under humid conditions of soil and climate, it combines most of the essential

features of a good perennial fodder crop, namely, ease of propagation, high productivity, excellent nutritive quality and palatability, general hardiness, and ability to exclude extraneous weed-growth. It gives only poor returns during prolonged dry seasons, and it has a second more serious drawback in the risk of dissemination to arable land, where it becomes an obnoxious weed. In consequence, it is recommended for use only in localities that can be effectively isolated from valuable arable land. This isolation may be achieved either by the observance of certain precautions in the manufacture of the farmyard manure, or by utilizing the crop on a system of controlled rotational grazing. In consideration of its many sterling qualities, Para Grass has now been included in a yield trial along with Guatemala Grass, Uba and Co. 213 Canes. Of the other varieties, the Guatemala Grass is considered to be a good all-round performer of average nutritive quality. It is admirably adapted to local conditions of climate and soil. In Trinidad, Elephant Grass must be condemned on account of its susceptibility to fungal infection. It may be possible to segregate a resistant strain, which, if it maintains the many good features that have made Elephant Grass so popular in other countries, would certainly have great cropping possibilities. The Co. 213 is superior to the Uba, which in the past has been one of the favoured perennial fodders sown in Trinidad. The Coimbatore Cane is undoubtedly worth a trial on any new areas that have to be planted in a cane crop required for fodder. The Guinea Grass is a variety that cannot be recommended as a general-purpose soilage crop for local conditions.

The variety, the height of cutting, and the length of the period between harvests, all influence the regeneration-habit of the ratoon-crops. It is possible by adopting an appropriate harvesting technique to combine rapid ratooning with multiple tillering and vigorous stool-development. With most varieties this will coincide with a cutting-rotation of approximately 3 months and herbage mown some 6 to 10 in. above ground-level.

Acknowledgements.—The author acknowledges with pleasure his indebtedness to the members of the Staff of the Chemistry Department of the Imperial College—Professor Hardy, Mr. Duthie, and Mr. Rodriguez—for undertaking the chemical analyses of the various samples of fodder grass collected. Their co-operation has been greatly appreciated.

REFERENCES

1. D. D. Paterson, The Influence of Time of Cutting on the Growth, Yield, and Composition of Tropical Fodder Grasses. J. Agric. Sci., 1933, **23**, 615.
2. —— The Growth, Yield, and Composition of Certain Tropical Fodders. Ibid., 1935, **25**, 369.
3. Anon., East African Pasture Grasses. Kew Bulletin, 1926, **1**, **2**.
4. H. F. Macmillan, Tropical Gardening and Planting, London, 1925.
5. Noel Deerr, Cane Sugar, London, 1921.
6. J. L. B. Kincaid, Growth and Composition of Fodder Crops in Trinidad. Imp. Coll. Trop. Agric., Dissertation (unpublished).
7. F. Hardy, Chief Soil Types of Trinidad. Proc. Agric. Soc. Trinidad and Tobago., **35**, 443.

8. R. G. STAPLEDON *et al.*, Welsh Plant Breeding Station, Aberystwyth, Bull. No. 3 (Series H), 1924.
9. H. E. WOODMAN, D. L. BLUNT, and J. STEWART, J. Agric. Sci., 1926, **16**, 205, *et seq.*
10. C. C. WEBSTER, The Composting of Crop Residues in the Tropics. Imp. Coll. Trop. Agric., Dissertation (unpublished).
11. R. D. ANSTEAD, Activated Composts. J. Inst. Sanitary Engineers, June 1932.
12. F. HARDY, Synthetic Organic Manure. Trop. Agric., 1928, **5**, 173.
13. C. P. WILSIE and M. TAKAHASHI, Napier Grass—A Pasture and Green Fodder Crop. Hawaii Agric. Expt. Stat., Bull. No. 72, 1934.

(*Received June 3, 1935*)

Typical stools of the individual grasses taken twelve weeks after harvest. This is reckoned to be approximately the correct time to cut them for fodder, as on a three-month rotation it is possible to combine fair nutritive quality, high yields, and longevity

17

THE DEVELOPMENT OF LIVE STOCK IN TANGANYIKA TERRITORY

I. ACTUAL AND PROPORTIONAL WEIGHTS OF THE VARIOUS PARTS OF THE BODY OF ZEBU CATTLE

M. H. FRENCH

(*Biochemist, Department of Veterinary Science and Animal Husbandry, Mpwapwa, Tanganyika Territory*)

WITH PLATES 3, 4

THERE are few, if any, places in the world where meat costs less than it does in Tanganyika Territory, and this fact should offer a big incentive to any commercial organization to investigate the possibility of utilizing Tanganyika stock for the raw material of a meat industry. Among the first things such a firm would require would be a full description of the type of stock, and of the weights and proportional distribution of the tissues and organs of the animals.

In Tanganyika there are approximately five million cattle [1], but owing to the fact that two-thirds of the Territory is infested with tsetse flies, the cattle population works out at about 40 per square mile of 'fly-free' country [2]. Furthermore, in much of this fly-free portion, East Coast fever is enzootic and keeps the cattle population below this concentration, with the result that some areas are very grossly overstocked whilst others carry a very sparse cattle population. Stock from the different areas will therefore vary greatly in size and condition.

Owing to the seasonal rainfall, periods of good grazing alternate with long intervals of drought. In the dry season the animals lose a large proportion of the weight which they gained during the period of good grazing [3], and so the rate of growth is very slow, and in the overstocked areas the animals never reach their potential maximum development. In some areas overstocking, together with food and water shortage, becomes so acute that thousands of stock die annually from starvation.

Owing to the spread of tsetse flies, progressive soil erosion, and the increase in the proportion of land under cultivation, overstocking is tending to become more widespread. There is thus a very definite surplus of stock that could be used for a meat industry with advantage to the remaining cattle population.

In the native social community the position of live stock differs considerably from that in civilized countries. To the native, the possession of live stock is the means of acquiring prestige amongst his fellow natives. Cattle are so bound up with social customs, expecially marriage transactions, that the native develops a profound love for them, and places on them a regard far in excess of their monetary value. In past periods of famine the natives have been known to die of starvation rather than kill their already half-starved cows.

This reluctance of the native to sell his stock, and particularly his female stock, is gradually being overcome through education and contact with civilization. As the native is educated to need more and more

articles from other countries, the need of cash will become more general and he will be encouraged to sell more of his stock. This change would take place the sooner if a ready market existed for every class of animal. Any firm opening a meat factory may anticipate the availability of a fairly large annual supply of stock.

The object of this investigation was to find out the weights and proportional distribution of the tissues in the cattle slaughtered in the Mpwapwa abattoir during a period of twelve months. The animals brought to this abattoir are representative of the average type sold in the cattle market of the Territory. In size they are mid-way between the larger Masai oxen and the smaller cattle from the overstocked Usukuma areas.

The stock markets are the collecting foci of the cattle-producing areas, from which traders purchase stock for transport and re-sale to the cattle-consuming areas. At present the poor-conditioned, stunted, or half-starved cattle are refused by the traders, and so the stock sold in the markets represents the better class of animal.

No fattening-up for the butcher takes place, of course, and the animals slaughtered and measured during the past year do not represent fat stock but merely those in better condition. In this important respect the figures to be presented differ from those obtained by workers in other parts of the world, where only fat animals have been investigated.

The cattle to be found over the greater part of Tanganyika are of the hardy zebu breed. This is a small breed, with a large hump and short horns. Usually they have narrow sloping hind-quarters, but are fairly deep-chested and possess a relatively large heart-girth. The skin is of no more than medium thickness, and covered with short smooth hairs, which may be of any colour. The quality of the meat, as judged by that from the early-maturing English breeds, is poor, and the amount of inter-muscular fat is very small, so that no 'marbled' joints can be obtained. The amount of fat in the carcasses varies considerably with the season and also with the age of the animal. Usually, too, there is little internal fat.

Owing to the presence of a large Mohammedan following amongst the native population, all animals in public abattoirs are slaughtered according to the Mohammedan laws, i.e. by cutting the throat cleanly to the spinal column.

This is the best method of bleeding an animal, and the result is that very little blood is left behind in the blood-vessels of the carcass. In this method of slaughter the blood spurts out with such force that it is often impossible to collect it completely, and to estimate the amount of blood in the body.

In the tables below the various headings are self-explanatory, but the following need a few qualifying remarks:

The *head* is weighed with its skin, but after the tongue and horns have been removed; it is severed from the body between the atlas and the cranium.

The *tail* does not represent an absolutely constant fraction, since some butchers prefer to leave a few inches attached to the carcass, whilst others sever the tail at the rump. The 'tail' is weighed without its skin, and for the weighings recorded in Table 2, it was removed at the rump.

The heading *feet* includes everything below the hock and knee-joints.

The *hump* is the result of a musculo-fatty development of the rhomboideus muscles and consists of layers of muscle interspaced with layers of fat. It is the only 'marbled' piece of meat in the body. The hump varies greatly with the condition of the animal, and may be a foot or more in height, or not larger than a man's hand. Fig. 3 (Plate 4) shows a longitudinal section through a good type of hump. In the present investigation it was removed as neatly as possible so as to leave the carcass, over the withers, the same shape as in a humpless breed of cattle.

In hot countries it is impossible to keep meat for any length of time and so the animal is usually cut into portions almost at once and eaten within 48 hours of slaughter. All weights for the carcass are 'hot' weights therefore, as the splitting of the carcass is done whilst this is still hot. The cut, dividing the side into fore- and hind-quarters, is made between the 10th and 11th ribs, so that three ribs are left on the hind-quarters.

Except in the larger European communities of this Territory the carcasses are not jointed as in Europe, but the butcher just cuts off a kilo as required. For this reason no figures could be obtained showing the proportions of the various 'joints' in the carcass.

During the year, 313 head of stock were slaughtered in the Mpwapwa abattoir. The slow rate of growth, and the fact that the beasts were not brought to the slaughter-house by the breeder, prevented any accurate determination of their ages. For the purposes of this article the animals are grouped according to the number of permanent incisors they were showing.

The distribution of the various types of stock slaughtered during the investigation is shown in Table 1:

TABLE 1. *Animals Slaughtered in Mpwapwa Abattoir 1934–1935*

	Males	*Females*	*Total*
Full-mouth stock . .	120	27	147
6-tooth stock . . .	40	4	44
4-tooth stock . . .	67	8	75
2-tooth stock . . .	43	4	47

These figures illustrate with what reluctance the native will part with female stock; when he does so it is because the animal is either barren, or gives insufficient milk for rearing a calf. Occasionally he will sell virgin heifers, but he hates selling anything he knows is capable of breeding and rearing offspring, and will only part with such stock as a last resort.

The average weights of the various tissues are given in Table 2. The figures presented in this table show the relative changes in the organs with increasing age, and also what differences can be expected between male and female cattle. In the mature zebu, as was found by Hammond [4] for British breeds of cattle, the carcass-weight, head, and hide are heavier in the males than in the females. The reverse is true of the suet fat and tongue. Hammond found the stomachs and intestines heavier in the females than in the males, but this does not appear to be so for the zebu breed.

TABLE 2. *Average Weights of Carcasses and Individual Tissues (lb.)*

Type of stock	*Full-mouth stock*			*6-Tooth stock*			*4-Tooth stock*			*2-Tooth stock*		
Sex	*Both sexes*	*Males*	*Females*	*Both sexes*	*Males*	*Females*	*Both sexes*	*Males*	*Females*	*Both sexes*	*Males*	*Females*
No. recorded	*147*	*120*	*27*	*44*	*40*	*4*	*75*	*67*	*8*	*47*	*43*	*4*
Fore-quarters	128·2	130·2	119·0	113·7	114·5	106·5	108·4	109·2	106·7	91·5	90·1	106·4
Hind-quarters	132·2	133·4	126·7	122·6	122·5	124·1	114·0	114·7	108·1	100·1	98·6	116·1
Carcass	260·4	263·6	245·7	236·3	237·0	230·6	224·4	223·9	214·8	191·6	188·7	222·5
Head	26·42	26·98	23·86	25·10	24·73	28·75	24·14	24·3	22·80	22·43	22·7	19·50
Horn	1·68	1·64	1·86	1·26	1·28	1·10	1·27	1·27	1·24	0·76	0·79	0·41
Tongue	2·19	2·17	2·28	1·90	1·95	2·20	1·94	1·94	1·97	1·48	1·52	0·96
Tail	1·50	1·55	1·28	1·26	1·28	1·06	1·20	1·21	1·11	0·90	0·92	0·69
Hide	31·55	32·13	28·98	30·79	31·11	27·50	30·03	30·54	25·70	25·02	25·30	21·87
Feet	10·60	10·16	12·92	10·43	10·33	11·47	10·01	10·09	9·31	8·78	8·8	8·52
Hump	5·90	6·11	4·95	4·80	4·74	5·36	4·21	4·21	3·89	3·80	3·79	3·85
Heart	2·14	2·21	1·80	1·90	1·87	2·20	1·91	1·85	2·48	1·64	1·65	1·51
Liver	7·09	7·16	6·78	7·26	7·18	8·11	6·83	6·86	6·60	5·90	6·00	4·81
Spleen	1·78	1·85	1·50	1·70	1·71	1·51	1·42	1·60	1·17	1·29	1·30	1·10
Lungs	7·35	7·45	6·89	6·80	6·97	4·06	6·49	6·55	5·73	5·55	5·54	5·64
Kidneys	1·38	1·38	1·38	1·25	1·25	1·24	1·19	1·18	1·27	1·04	1·03	1·15
Suet fat	3·80	2·77	8·33	3·18	3·24	2·61	3·10	3·10	3·15	1·62	1·51	2·89
Caul fat	4·07	4·14	3·76	2·77	2·77	2·75	3·20	3·24	2·88	1·78	1·82	1·38
Stomachs and intestines	34·12	34·53	32·30	32·60	32·82	30·37	30·56	30·83	28·31	29·02	29·28	26·80
Contents of alimentary canal	84·35	84·36	84·31	75·80	75·66	77·15	64·23	64·01	66·05	55·10	55·10	55·07

The average carcass-weight is seen to be very small and about 260 lb. for an adult animal. Of the 120 full-mouthed males slaughtered, 10 had a carcass-weight of over 350 lb., and averaged 381·1 lb. As will be seen by reference to Table 3, these animals gave a higher carcass-yield than the smaller animals, possessed more internal fat, and had a smaller percentage of offal.

The carcass-weight varies in the full-mouthed stock from 190 to 495 lb., and that of the hides ranged from 20 to 50 lb. It will be seen that the figures in Table 2 confirm the statement of Lichtenheld [5], who quoted Mannleitner, that 2-year-old oxen would reach up to 106 kg. carcass-weight and that 5-year-old oxen might go up to 200 kg.

The hump, which is not met with in Europe, when taken from a fat animal, boiled, and eaten cold, is a delicious food, but when taken from a poor animal, it is tough and unappetizing. The weight of the hump in these studies varied from 2 to 18·7 lb. Lichtenheld quotes 11 kg. as the weight of a hump from an Ugogo ox.

In these full-mouthed cattle we find that the hind-quarters are slightly heavier than the fore-quarters. The carcass-weight, with the hump left on and with the kidneys and kidney-fat not removed, is divided into 50·8 per cent. hind-quarters and 49·2 per cent. fore-quarters when the cut dividing the two is made between the 10th and 11th ribs. The hind-quarters thus form a higher proportion of the total carcass than would at first be expected; the percentage is only slightly below that for improved breeds. For South African stock exported to London, Fourie's figures [6] show the hind-quarters as representing 51·1 per cent. of the carcass, whilst for Grade European X Zebu cattle in Kenya I have shown that the hind-quarters represent 51·8 per cent. of the total carcass [7]. It is difficult to compare these figures with those given in the standard American publications, because the fore- and hind-quarters are divided between the 12th and 13th ribs.

As weigh-bridges are not installed at either the abattoirs or stock markets in this Territory, no exact live-weights could be obtained, and so the tissues cannot be expressed as a percentage of the total live-weight. From weights recorded at the Veterinary Laboratory, however, the cattle of this Territory vary in weight from large Masai oxen, averaging about 800 lb. when in good condition, to the small, stunted, and badly fed animals of the worst overstocked areas, which may weigh as little as 400 lb., even when apparently mature and in fair condition. The average weights of full-mouthed cattle bought in the stock markets would be about 500 lb. live-weight. Figs. 1 and 2 (Plate 3) show average full-mouthed oxen. In only 48 of the full-mouthed cattle recorded in Table 2 was it possible to record the weight of the blood in the body; the average weight of blood in these 48 animals was 18·13 lb., and their average carcass-weight 251·6 lb.

Since the carcasses and organs were all weighed hot and immediately after removal from the animal, the loss due to evaporation and cooling was very little. If we take the losses involved during slaughter, skinning, opening, and cutting up the carcass as approximately 1 per cent., we can calculate from the weights of the organs and the carcass the total live-

weight of the animal slaughtered. If we do this with the average figures obtained for full-mouthed stock of both sexes, the average live-weight is 510 lb.—a figure which wide practical experience confirms. By using this average live-weight, the proportional distribution of the various tissues has been determined and is set out in Table 3, together with the corresponding figures found by Hammond [4] for the average of all British breeds of cattle.

TABLE 3. *Weights of the Organs, &c., of Zebu Cattle, expressed absolutely and in terms of Live-weight. Comparison with British Cattle*

	Zebu cattle				*British cattle*
	Full-mouthed cattle		*Full-mouthed, with over 350 lb. carcass*		*Steers*
	Weight of organ	*Weight as per cent. of live-weight*	*Weight of organ*	*Weight as per cent. of live-weight*	*Weight as per cent. of live-weight*
	lb.		lb.		
Live-weight	510	100	700	100	100
Carcass	260·4	51·1	381·1	54·4	64·6
Head and horns	28·1	5·5	34·7	4·9	3·93
Feet	10·6	2·1	11·8	1·7	
Hide	31·6	6·2	43·6	6·2	6·7
Tongue	2·2	0·4	2·7	0·4	0·8
Tail	1·5	0·3	1·7	0·2	
Hump	5·9	1·2	12·0	1·7	..
Heart	2·1	0·4	2·9	0·4	2·55
Liver	7·1	1·4	8·8	1·2	
Lungs	7·4	1·4	9·3	1·3	
Kidneys	1·4	0·3	1·6	0·2	..
Spleen	1·8	0·3	2·0	0·3	..
Stomachs and intestines	34·1	6·7	44·3	6·3	..
Contents of alimentary canal	84·4	16·5	91·3	13·0	..
Caul fat	4·1	0·8	9·4	1·3	..
Suet fat	3·8	0·8	9·5	1·4	..
Blood	18·1	3·5	25·0	3·6	2·3
Loss	..	1·1	..	1·5	..

The average zebu ox is less than half the weight of the average British steer, and a good zebu ox compares in size only with the smallest of the British breeds. Hammond has shown that the smaller animals in a given breed yield a lower percentage of carcass than do the larger animals of the same breed. This fact is also clearly demonstrated for zebu cattle in Table 2. It is to be expected, therefore, that the carcass of zebu cattle will not only be smaller, but that it will also represent a smaller proportion of the total live-weight than it does in British breeds.

The animals recorded by Hammond were cattle fattened for the Smithfield Show and therefore were better finished and carried more adipose tissue than the cattle recorded at Mpwapwa.

In the zebu cattle, the head, hide, and feet form a very much higher proportion of the total animal than they do in the British breeds recorded by Hammond, or in the beef-breeds exported from America, Australia, Argentina, and South Africa. The same applies for the heart, liver, lungs, and blood; and is probably also true for the stomachs and intestines, but Hammond's figures do not represent these organs freed from their contents so completely as do the present series. The internal and external fat deposits are much greater in the European breeds of cattle than in the zebu.

The average carcass in the Territory does not carry the finish required by the English markets. Generally there is a lack of subcutaneous fat, although in the older and better-conditioned oxen the carcass may be covered with a thin layer of fat. Further, the fat of the zebu carcass is most often yellowish in colour, which is to be expected in grass-fed animals. The meat is often dark, a result of long walks in search of scanty grazing. Figs. 4 and 5 (Plate 4) show a moderately good carcass.

Carcasses from the Tanganyika breed of native cattle could therefore find no place on the English market. They are better suited for a local canning or extracting industry, for conversion into fertilizer or feeding-stuffs for animals, and for the preparation of medicinal extracts from glands and liver. The lower percentage of fat in the carcass makes the local stock particularly suitable for these industries, especially the canning industry.

During the twelve months in which these figures were collected, 120,790 cattle were sold in the Tanganyika markets, realizing £103,762 10*s*., i.e. an average price of 17·18*s*., the range being from 5*s*. to 65*s*. per head, according to the market, the season of the year, and the type of stock.

The average price of the hides to the butcher for this period was between 4*s*. and 5*s*. each. If we take the average carcass-weight as 200 lb., which is less than that found at Mpwapwa, then the cost of 100 lb. of carcass is approximately 6·5*s*., inclusive of the value of the internal organs, all of which are eaten by the native. In other words 1 lb. of carcass costs ¾*d*., and nowhere in the world, so far as I can ascertain, does meat cost less.

Summary

A description is given of the zebu stock, which is the breed found throughout practically all the cattle areas of Tanganyika Territory. The position of the stock in the native community is discussed in its relation to the marketing of live stock.

Figures are given to show the average live-weights of the zebu cattle, and of the weights of the various organs in the body. The type of carcass yielded by these animals is described, together with the uses to which these carcasses are suited.

The average market price of over 120,000 stock sold during the period of investigation was 17·18*s*. The cost per lb. of carcass was ¾*d*.

REFERENCES

1. Ann. Rept. Dir. Vet. Sci. & Anim. Husb., Tanganyika Territory, 1934.
2. Memorandum on the Economics of the Cattle Industry in Tanganyika, Dept. Vet. Sci. & Anim. Husb., Tanganyika Territory.
3. M. H. FRENCH, Ann. Rept. Dir Vet. Sci. & Anim. Husb., Tanganyika Territory, 1932, p. 63.
4. J. HAMMOND, J. Agric. Sci., 1920, **10**, 233.
5. LICHTENHELD, Der Pflanzer, 1913, **9**, 261.
6. N. F. FOURIE, Farming in S. Africa, 1935, **10**, 283.
7. M. H. FRENCH, Empire J. Expt. Agric., 1936, **4** (in the press).

(*Received October 18, 1935*)

FIG. 1.

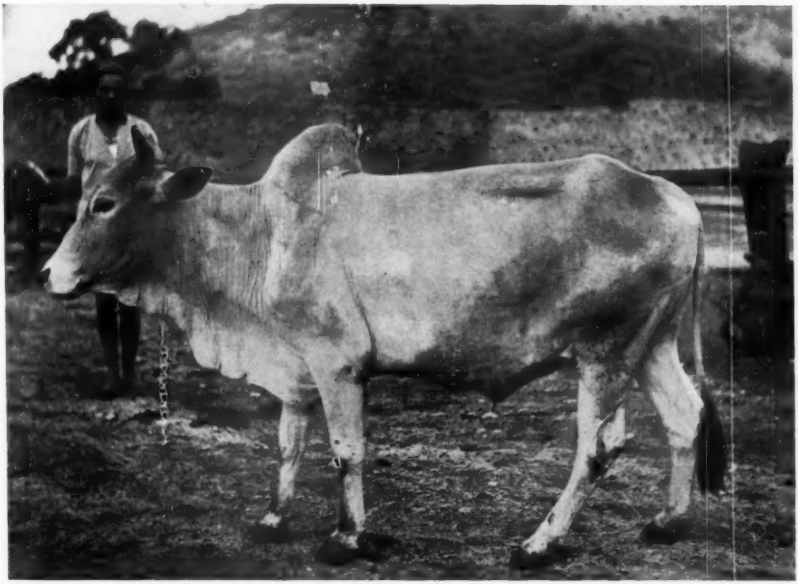


FIG. 2.

Typical Zebu oxen of 500 lb. and 550 lb. live-weight, respectively

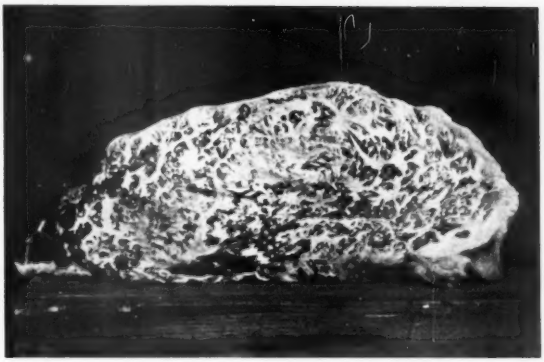


FIG. 3. A good hump cut longitudinally

FIG. 4. FIG. 5.

A good carcass from a Zebu ox

TECHNIQUE OF DIGESTIBILITY TRIALS WITH SHEEP AND ITS APPLICATION TO RABBITS

S. J. WATSON AND E. A. HORTON

(I.C.I. Agricultural Research Station, Jealott's Hill, Bracknell, Berks.)

WITH PLATE 5

Introduction.—In the work carried out at this Station on the nutritive value of grassland herbage, a large mass of data has accumulated in connexion with the feeding-value of the fresh crop, and of hay, silage, and artificially dried grass. Examination of the literature shows a dearth of accurate figures for such foodstuffs under conditions existent in the British Isles, though the work of Woodman at Cambridge [1] has added much to our knowledge of the feeding-value of fresh grass.

The composition and digestibility of most farm-grown foodstuffs is fairly constant, since they are fed mainly at the stage of maturity, and thus may be classified with a certain degree of accuracy. With grassland herbage it is otherwise: as it passes through its various stages of growth it is altering continuously in composition; its nutritive value depends on the stage of growth at which it has arrived. Hence a chemical analysis is not in itself sufficient for the determination of the feeding-value. This depends also on the proportion of the foodstuff which can be digested. By feeding an animal with a known weight of a feeding-stuff of known analysis and collecting and analysing the dung, it is possible to determine how much of the feeding-stuff is digested by the animal.

Technique.—The animals used for this work are sheep, the early experiments at this Station being carried out on Suffolk-half-bred-cross wethers, and the later and greater part of the work on Kerry-cross wethers (Kerry ewe–Southdown ram). Two Ryeland-half-bred-cross wethers (the half-bred being the usual Border Leicester on Cheviot) have also been used. No differences have been noted in individuals or between the breeds. When new sheep have been brought in for experiment, they have usually had a short period in the digestibility crates, in order to get them accustomed to the confined quarters and the feel of the harness. On such occasions no trouble has been experienced with either feeding or harness. The sheep are weighed before and after each trial, and fed on a ration at the plane of maintenance.

The experimental ration is fed to the sheep in a preliminary period before the proper feeding-period begins. The length of the preliminary period varies according to the time it takes for the animal to eat its ration freely, and may be cut down to two days. The sheep are then placed in the digestibility crates and equipped with harness. The experimental period, during which the ration is accurately weighed, starts the next day. The uneaten residues, if any, are collected each morning before the first feed is given. The dry-matter content of these residues is determined, and the composite sample made up from the whole of the residues in the experiment is analysed.

Owing to the lag in the passage through the alimentary tract, a period of forty-eight hours has to be allowed before the first collection of excreta takes place. When the last experimental feed has been given, there will still be two days' excreta to be collected. During these two days the sheep receive the same amount of food as they did during the experimental period.

Sampling.—Succulent foodstuffs, such as grass and silage, are weighed out daily, and a representative sample of 200 gm. is taken for dry-matter determination. The daily dry-matter samples are mixed at the end of the trial, and a complete foodstuffs-analysis carried out on this mixed sample. For silage, samples of the fresh material are taken daily for nitrogen-determination, and the total nitrogen ingested is calculated from these figures, and compared with the figure obtained from the dried sample. The loss of nitrogen in drying may vary considerably with the nature of the fermentation that has taken place in the silage.

With foodstuffs which will keep without change other than a slight variation in moisture-content, such as hay or dried grass, all the feeds for the whole trial are weighed out at the same time and stored in scrim bags. At the same time a sub-sample is taken for moisture-determination and subsequent analysis.

In summer the faeces are weighed every day, and nitrogen is determined in duplicate on 5 gm. samples of fresh faeces, which are thoroughly mixed by pounding them in a mortar. At the same time, for greater ease of sampling, an aliquot part equal to one-tenth of the total weight of the well-mixed fresh faeces is weighed into a flat-bottomed tin, and is put into a drying-room at 40° C. After all the samples have been collected, they are taken out of the drying-room, allowed to come to constant moisture-content in the laboratory, weighed, ground, and mixed thoroughly in the same way as the foodstuff. During winter the excreta collected on two successive days are mixed and treated as one sample.

The urine is collected daily, starting with the first day of the experimental period, and the nitrogen is determined on 5 c.c. portions. One-twentieth of the volume voided is taken each day, and is stored between chloroform and toluene. This composite sample is, where necessary, analysed for mineral constituents at the end of the trial.

Latterly the urine has been allowed to run away, since it is not needed unless the nitrogen or mineral balance of the animals is to be determined. This is not normally done, as it seems certain that accurate data for a balance trial of this type can only be obtained in long-period experiments, whereas the digestibility trial will give accurate results with an experimental period of 8 up to 14 days.

Equipment.—The construction of the digestibility crates used is shown in Plate 5. The inside of the crate is covered with 'Uralite', and a galvanized-iron grid is let into the floor. Below this is a lead-lined funnel which connects with a pipe passing through the bottom of the crate. The urine passes down this tube into a Winchester placed underneath.

The feeds are weighed out into boxes which slide into the front of the crate, and can be removed easily for the collection of the uneaten residues.

Distilled water is provided in a trough.

The sheep are fitted with a stout leather collar, which is attached to the crate by a length of chain. The dimensions of the crate and the length of the chain are such as to permit of free movement without allowing the animal to turn right round or get its hind legs off the grid by more than a few inches. No loss of urine has been noticed with the crates. The sheep are quite free to lie down, and spend most of their time in that position.

The faeces are collected in a special waterproof bag, which is attached by a webbing harness that causes no chafing. The bag is opened and closed by means of a 'lightning fastener', which passes down the full length of the median line of the bag. The faeces can thus be removed quite simply without unfastening the harness or detaching the bag.

No trouble has been experienced with any of the sheep chosen for experiment. Several of them have been continuously in the crates for periods of two months without any apparent effect on health or appetite. Special care must be taken of their feet, as the sheep are apt to become footsore unless the horn is cut down systematically. The Kerry-cross wether has been preferred merely from a practical standpoint, as no difference in the results has been noticed between the different breeds. The only digestive disturbance noted during the whole of the trials was due to the feeding of frozen mangolds. The sheep have varied in weight between 95 lb. and 120 lb., and the ration fed has varied between 2 lb. and 3 lb. of dry-matter per day. The live-weight has been maintained without exception while on experiment.

Determination of digestibility.—The object of the digestibility trial is to determine the amount and composition of the food and solid excreta. The part of the food which has been digested is then found by deducting the constituents of the faeces from those of the original food.

The following tables show how the balance-sheet is constructed. A sheep was fed daily for 10 days with 4 kg. of silage containing 23·13 per cent. dry-matter, and during the 10 days it was on trial there was a total yield of 2,240 gm. of air-dried faeces, containing 94·78 per cent. dry-matter.

The chemical analysis gave the following composition for the dry-matter of the silage and that of the air-dried faeces:

	Moisture	*Ether extract*	*Crude fibre*	*Crude protein*	*N-free extract*	*Organic matter*	*True protein*	*Ash*
Silage	..	5·18	24·99	18·22	42·54	90·93	9·21	9·07
Faeces	5·22	5·95	14·60	18·00	38·53	77·08	16·83	17·70

The amounts digested are calculated thus:

	Dry-matter	*Organic matter*	*Ether extract*	*Crude fibre*	*N-free extract*	*Crude protein*	*True protein*
	gm.	gm.	gm.	gm.	gm.	gm.	gm.
Intake—silage	9,252	8,413	479	2,312	3,936	1,686	852
Output—faeces	2,123	1,727	133	327	863	403	377
Digested	7,129	6,686	346	1,985	3,073	1,283	475
Amount digested per cent.	77·05	79·47	72·23	85·86	78·07	76·10	55·75

The figures in the last row are termed the 'coefficients of digestibility'. It will be seen that the assumption is made that the whole of the dung consists of undigested food. This assumption is, of course, not correct, for the faeces always contain small quantities of substances which are metabolic waste products.

Metabolism experiments to determine digestibility are important, in that they are the only means by which a direct measure of the amount of any given food utilized by the animal body can be obtained. Efforts that have been made to determine the availability of a food *in vitro* have been successful only in the case of the protein. This has been effected by artificial digestion in acid gastric juice, and has served to determine the total quantity of protein which is digestible. Such determinations tend to measure the true digestibility in the digestive tract rather than the *effective* digestibility as measured by animals. The literature shows that the *in vitro* methods nearly always give coefficients which are higher than those obtained by animal experiments. This is, of course, due to the presence in the faeces of metabolic residues not directly derived from the food.

Attempts have been made to determine the amount of metabolic residues in the faeces by feeding a nitrogen-deficient ration. Kellner [2], working with herbivora, suggested a value of 0·4 gm. nitrogen per 100 gm. of organic matter digested. Pfeiffer [3] carried out a number of experiments with pigs. In the first period the pigs received a normal ration of barley-meal, in the second period a diet that was practically nitrogen-free, and in the third one containing completely digestible protein. In the second period he found that the whole of the faecal nitrogen was soluble in pepsin-hydrochloric-acid solution (gastric extract). The figures he obtained with pigs agreed with Kellner's value for herbivora. The work was then repeated, using goats. The amount of metabolic nitrogen per 100 gm. of organic matter digested was found to be 0·51 gm., with a range of 0·43 to 0·76 gm.

Morgen *et al.* [4], feeding a nitrogen-free ration to sheep, found that the average excretion of metabolic nitrogen was 0·57–0·64 gm. per 100 gm. organic matter digested. Crowther and Woodman [5], using sheep, obtained an average value of 0·52 gm. metabolic N per 100 gm. of organic matter digested.

Kellner [2] had tried to find the amounts of nitrogen remaining undissolved in artificial digestion of fodder with acid gastric juice, and found that these were lower than the amounts of nitrogen excreted in the dung of animals fed with the same fodder. It was assumed that the difference between the artificial digestion and the animal digestion was a fairly accurate measure of the quantity of nitrogen passing from the body to the faeces, i.e. the residues of metabolism. Kellner [6] makes no use of these figures in his book, and states that as there are no methods of estimating the metabolic residues in the faeces with certainty, the assumption has to be made that all nitrogen found in the faeces must be due to undigested food.

Pfeiffer [3], however, concluded from his experiments that the nitrogenous products of metabolism must be taken into account in determin-

ing the digestibility of the protein in animal experiments. Experiments were carried out to determine the digestibility of certain feeding-stuffs, (i) with animals, (ii) by artificial digestion, and (iii) with the value obtained in the animal experiment corrected for the nitrogen-containing metabolic residues. This last-mentioned value was obtained by digesting samples of the fresh faeces with 200 c.c. of pepsin solution at blood-temperature for 24 hours, with gradual addition of HCl, until a concentration of 1 per cent. was reached. The solution was filtered, washed with water, alcohol, and ether, and the nitrogen determined on the residue. The nitrogen soluble in the pepsin solution was considered to be due to metabolic residues. The figures are set out in the following table, together with those obtained by artificial digestion as determined by the modified Stützer method [7], using pepsin followed by a pancreatic extract.

TABLE 1. *Digestibility Coefficients of the Crude Protein of some Feeding-stuffs as determined by Different Methods* (*Pfeiffer* [3])

	A *Old Method animal experiments. No correction for metabolic residues* (*Average of 2 goats*)	B *Animal experiments. Correction applied for metabolic products in faeces* (*Average of 2 goats*)	C *Artificial digestion. Stützer method* [7] *using pepsin and pancreatin*
Period 1	64·31	78·55	79·43
„ 2	75·35	84·60	85·59
„ 3	74·95	86·35	86·78
„ 4	76·29	88·68	89·17
„ 5	79·59	90·07	89·31
Hay	64·31	78·55	79·43
Peanut cake	89·63	92·41	93·56
Dried beet (Period 3)	58·70	83·25	81·88
Lucerne hay	76·29	88·68	89·17
Dried beet (Period 5)	67·87	88·12	81·88

The values for the individual foodstuffs are calculated from the results obtained with the mixed rations fed in Periods 1 to 5. There is good agreement between the values obtained in the artificial digestion and the values obtained in the animal trials when corrected for metabolic residues in the faeces.

The figures obtained at Jealott's Hill when feeding a ration of artificially dried grass at the plane of maintenance are given in Table 2.

TABLE 2. *Digestibility Coefficients of Artificially Dried Grass obtained by Different Methods*

(Average of six sheep)

Animal experiments uncorrected for metabolic residues	*Animal experiments corrected for metabolic residues*	*Artificial digestion. Sjollema-Wedemeyer method* [8]
63·30	76·24	76·95

The pepsin-HCl-soluble nitrogen in the faeces, which was assumed to represent the nitrogen due to metabolic residues, gave an average value of 0·34 gm. per 100 gm. of dry-matter intake, with a range of 0·31–0·40 (0·56 gm. per 100 gm. organic matter digested, with a range of 0·48–0·67). Apparently, if there is a difference of 12·0 to 15·0 units between the digestibility coefficients obtained by artificial and by animal experiments, the correction of the animal figures for metabolic residues in the faeces holds good. In view of some of the figures obtained at Jealott's Hill and also by Woodman [9] at Cambridge, it would appear, however, that there is not always such a considerable difference between the apparent and the true digestibility coefficients.

TABLE 3. *Digestibility Coefficients of Crude Protein of Pasture Herbage*

(Stated as percentages)

Date of cutting	A *Artificial digestion*	B *Animal digestion*	*Column A–Column B*
April 27 Cambridge (Woodman)	83·5	79·3	+4·2
May 14 "	85·1	85·4	−0·3
June 1 "	81·7	81·1	+0·6
June 18 "	82·4	78·4	+4·0
July 9 "	80·1	77·1	+3·0
August 3 "	78·5	76·6	+1·9
August 24 "	81·3	78·9	+2·4
September 14 "	85·1	83·4	+1·7
October 5 "	84·5	84·0	+0·5
November 29 "	78·1	81·3	−3·2
October 2–10 Jealott's Hill	75·4	81·0	−5·6
" " " "	78·5	77·2	+1·3
" 17–25 " "	72·1	75·8	−3·7
		Average	+0·5

The application of the factor for metabolic residues would certainly produce anomalous results in the above figures.

In order to accept the digestibility coefficients obtained by correcting the figures from animal experiments for nitrogen due to metabolic residues, two assumptions have to be regarded as valid. These are, firstly, that as the protein has defied solution in the animal digestion, it will also be indigestible in the faeces when treated with pepsin-HCl solution, and secondly, that the nitrogen due to metabolic residues is soluble in the pepsin-HCl.

It is well known that whole maize and whole grain when fed to sheep frequently appear unchanged in the faeces. There is no reason to suppose that other foodstuffs with a high fibre-content, such as grass at a mature or hay-stage, is much more easily digested. The lignified cells can be seen clearly in the faeces of sheep, apparently quite unaltered. It is probable that the protein is protected in some degree by the presence of this indigestible material. This may be the explanation of the high digestibility of the protein in concentrates poor in lignified fibre, and of the difference between the protein-digestibility of young grass and of

grass at a mature stage. The protein from the latter is surrounded by tougher and more fibrous cells than that of the concentrates and the young grass.

The dried and *ground* faeces from animals fed on such fodder are, however, taken and further subjected to the action of pepsin-HCl under optimum conditions. It is not unreasonable to suppose that some of the residual food-protein which has escaped solution in the gut is now brought into solution. With reference to the effect of fineness of grinding, the following figures (Ashton, unpublished data, Jealott's Hill) are of great interest, as affecting the amount of pepsin-HCl-soluble nitrogen in a foodstuff:

TABLE 4. *Effect of Fineness of Grinding on the Pepsin-HCl-Soluble Nitrogen in Grassland Herbage*

Size of mesh:	$\frac{1}{4}$ in.	$\frac{1}{8}$ in.	$\frac{1}{16}$ in.	$\frac{1}{32}$ in.	$\frac{1}{64}$ in.
Nitrogen soluble in Pepsin-HCl (Wedemeyer) per cent.	1·11	1·54	1·57	1·70	1·76
S.E. mean of 3 . . .			0·0116		
Significant difference . . .			0·037		

It is easy to see the possible effect of the fine state of division of the ground faeces on the nitrogen that is found to be soluble in the subsequent treatment with pepsin-HCl.

From the foregoing figures it will be recognized that a definite figure cannot be accepted for metabolic nitrogen for all rations. Morgen and co-workers [4], and Mitchell and Hamilton [10] have shown that the roughage-content, together with the amount of dry-matter present, could alter the figure, so that it varies with the plane of nutrition.

It would therefore appear that the effective digestibility of the protein, as obtained directly by animal experiments, is the most suitable figure to use for practical purposes. It is a measure of the net utilization of the protein by the animal—in the sense that it represents the difference between the nitrogen ingested and that voided in the faeces, which, for an animal in nitrogen-equilibrium, is equal to the nitrogen passing from the blood-stream into the urine—whereas the artificial method is not. Furthermore, in no case have the corrected values been used in official calculations of food-values.

Starch equivalent and protein equivalent.—The best possible criterion of the energy and fattening value of a feeding-stuff is the 'starch equivalent'. This is not a theoretical figure, but a figure based on results obtained by direct practical experiment. These values were used by Kellner [6], and are based on the energy-content of the foods. Experiments were carried out to determine the fat-producing capacity of different feeding-stuffs, and the pure constituents thereof. Table 5 shows the data on which Kellner's formula for calculating starch equivalents was based.

A correction has, however, to be made for a loss of energy during the metabolic processes. In dealing with the concentrates and feeding-stuffs of low fibre-content, the starch equivalent may be worked out directly, applying Kellner's 'value number' (*Wertigkeitsfaktor*), but for roughages

it is customary to make a correction varying regularly with the percentage of total crude fibre in the food between 4 and 16 per cent. Where the amount is 16 per cent. or more, a deduction of 0·58 of starch equivalent is made for each 1 per cent. of total crude fibre. The factor falls in value with the total crude-fibre content of the fresh food between 16 and 4 per cent., and when it is 4 per cent. or less, the deduction is 0·29 of starch equivalent for each 1 per cent. of total crude fibre.

TABLE 5. *Kellner's Data for Calculating Starch Equivalents*

From	*Fat produced*	*Factor*
	gm.	
1 kg. (digestible) protein	235	0·94
1 kg. ,, fat from oil-cakes . .	598	2·41
1 kg. ,, fat from grain . .	526	2·12
1 kg. ,, fat from hay and straw .	474	1·91
1 kg. ,, starch	248	1·00
1 kg. ,, crude fibre . . .	253	1·02
1 kg. ,, sugar	188	0·76

A typical example is given below, showing how, if the digestible nutrients of a feeding-stuff are known, the starch equivalent may be calculated:

15·12 % digestible true protein × 0·94	= 14·21 %	starch equivalent.
3·32 % digestible fat × 1·91	= 6·15 %	,, ,,
33·21 % digestible nitrogen-free extract 14·55 % digestible crude fibre	= 47·76 %	,, ,,
	68·12 %	,, ,,
Deduct 18·38 % crude fibre × 0·58	= 10·66 %	,, ,,
	57·46 %	starch equivalent

That is to say, 100 kg. of this feeding-stuff is equivalent to 57·46 kg. of starch measured in terms of fat or energy production.

It will be noticed that the value for 'true' protein has been used throughout in the calculation of starch equivalents, according to Kellner's formula. Some doubt exists as to the correct figure to use in the case of silage, where there is always some break-down of the original 'true' protein.

The 'true' protein has been determined both in the feeding-stuff and the faeces by precipitation with copper hydroxide, according to Stützer [11].

For measuring the nutritive value of a foodstuff the starch equivalent must be supplemented by the protein-equivalent value. This is a figure suggested by the Departmental Committee for the Rationing of Dairy Cows [12], and consists of the mean of the values for the percentages of digestible crude and digestible 'true' protein.

There is considerable doubt nowadays as to the true value of the protein-equivalent figure. It seems certain that non-protein nitrogen may replace a part of the 'true' protein nitrogen in the ration without affecting the performance of the animal. Ammonium compounds [13,

14, 15] have been used as well as more complex nitrogenous substances, such as urea [16], and it is possible that in the near future the present-day conception of the nutritive value of nitrogen in the ration will have to be modified; it may prove that the total-nitrogen content is the best measure of the feeding-value of the nitrogenous compounds in the material in question. The work carried out to date on this question still requires confirmation.

Digestibility trials with rabbits.—All the digestibility trials quoted in the tables have been carried out with sheep as the experimental animals. There have been occasions when only small supplies of material have been available, insufficient for a complete trial with the sheep. It was thought that if rabbits provided a true measure of the digestibility of a food, as compared with the sheep, the technique of determination would be simplified, and materials, such as pure species of pasture plants, of which only small supplies may be available, could be tested.

Four trials were carried out with rabbits in 1933. The floors of the boxes consisted of wide-mesh netting, through which the faeces dropped to a close-mesh netting, placed at an angle, so that they rolled to a trough at the side. A tray was placed beneath the lower mesh to catch the urine, which ran into a beaker. The tray was washed down daily with distilled water.

The trials were carried out on three samples of grass from different fields, and on one sample of marrow-stem kale. The trials ran concurrently with sheep trials on the same materials.

The results obtained are compared in the following table:

TABLE 6. *Comparison of Digestibility Coefficients obtained with Sheep and Rabbits receiving the same Material*

	Grass 1		*Grass 2*		*Grass 3*		*Marrow-stem Kale*	
	Sheep	*Rabbit*	*Sheep*	*Rabbit*	*Sheep*	*Rabbit*	*Sheep*	*Rabbit*
Dry-matter	77·66	63·40	73·10	63·02	72·18	62·75	81·74	82·92
Organic matter	80·72	63·68	76·47	63·69	76·03	62·95	85·03	82·66
Ether extract	55·47	45·86	45·85	41·02	55·10	51·18	68·44	72·10
Crude fibre	83·97	46·88	78·39	50·12	78·25	50·96	74·32	54·93
N-free extractives	81·18	67·25	77·52	66·84	76·53	64·86	84·46	88·00
Crude protein	80·96	78·95	77·18	76·74	75·77	76·23	88·03	86·44
True protein	79·59	76·97	72·52	74·83	74·14	74·00	83·94	83·62

It is obvious that apart from the crude and 'true' protein coefficients there is a very poor agreement between the two animals in the trials with grass. Except for the crude-fibre digestibility there is good agreement in the kale experiment. As the crude-fibre content of the grass averaged 22 per cent. and that of the kale was 11·5 per cent., the depression of the digestibility of the fibre was not due to the different proportion of fibre in the diet. This low power of digestion of the fibre is evidently characteristic of the rabbit.

It may be concluded that rabbits do not offer a true picture of the

digestibility of grass as determined with sheep, except for the crude and 'true' protein values.

Possible use of indicator substances in digestibility trials.—Preliminary experiments have also been made in the use of indicator substances. The ratio of iron to the constituent under question in the ingested food and in the faeces affords a method of calculating digestibility coefficients without the actual measurement of the weight of fodder fed or the weights of faeces voided. It is necessary to know that the samples of the foodstuff and of the faeces are truly representative of the whole amount fed or voided, respectively.

It was found difficult to get any useful figures if the iron in the food was used as the indicator, since the amount present was small, and in consequence the accuracy of estimation was relatively low, and the ratio to any of the constituents in question is too wide. It is hoped in the near future to use an *added* indicator, such as a compound of chromium or titanium, which would be added at a predetermined rate to the foodstuff, and the ratio of it present in the food and in the faeces determined analytically.

If it is possible to evolve a simple technique, such as has been done in Sweden [17], it should prove a simple matter to obtain data on the digestibility of various crops at outside centres without undue trouble. All that is required is to ensure careful weighing out of the foodstuff fed and of the indicator used; careful mixing, so that the whole of the added material is ingested; and a technique for the collection of the faeces which will ensure that they are representative of the output over the experimental period.

Summary

The technique of digestibility trials with sheep is outlined, together with the methods adopted for calculating the digestibility coefficients and the starch and protein equivalents of different foodstuffs.

The correction of the protein-digestibility coefficient by making allowance for the metabolic nitrogen in the faeces is discussed, and reasons are advanced for retaining the uncorrected figures. The comparison of rabbits with sheep as instruments for determining digestibility has shown agreement only in the values for the protein. The rabbit does not digest fibre as efficiently as does the sheep, and values obtained with the former cannot be applied to the latter animal.

The possibility of using indicator substances in digestibility trials has been explored.

Acknowledgements.—We are indebted to Mr. H. J. Page, under whose direction this work has been done, and to Imperial Chemical Industries, Ltd., for permission to publish this paper.

REFERENCES

1. H. E. Woodman, *et al.*, J. Agric. Sci., 1926, **16**, 205–74; 1927, **17**, 209–63; 1928, **18**, 266–96; 1929, **19**, 236–65; 1930, **20**, 53–62; 1930, **20**, 587–617; 1931, **21**, 267–323; 1932, **22**, 26–71; 1932, **22**, 852–73; 1934, **24**, 93–104; 1934, **24**, 574–97.
2. O. Kellner, Centrbl. Agrikulturchemie, 1880, **9**, 763–5. Also Land. Vers. Stat., 1880, **24**, 435.

Crate and other equipment used in Digestibility Trials with sheep

3. T. Pfeiffer, J. für Landwirtschaft, 1883, **31**, 221; 1885, **33**, 149–92; 1886, **34**, 425–53. Also Z. physiol. Chem., 1886, **10**, 170, 561; 1887, **11**, 1.
4. A. Morgen, C. Beger, and F. Westhauser, Land. Vers. Stat., 1914, **85**, 1–104.
5. C. Crowther and H. E. Woodman, J. Agric. Sci., 1916–17, **8**, 429–47.
6. O. Kellner, The Scientific Feeding of Animals. Duckworth, London, 1915.
7. A. Stützer. Land. Vers. Stat., 1889, **36**, 321–8.
8. G. Wiegner. Anleitung zum quantitativen agrikulturchemischen Praktikum. Gebrüder Borntraeger, Berlin, 1926, p. 249.
9. H. E. Woodman. J. Agric. Sci., 1926, **16**, 205–74.
10. H. H. Mitchell and T. S. Hamilton, The Biochemistry of the Amino Acids. Chemical Catalog. Co., New York, 1929.
11. A. Stützer. J. für Landw., 1881, **29**, 473.
12. Report of the Departmental Committee on Rationing of Dairy Cows. H.M. Stationery Office, London, 1925.
13. H. Bareiss, J. für Landw., 1927, **75**, 265.
14. F. H. Ziemer. Biochem. Ztschr., 1931, **232**, 352.
15. P. Ehrenberg. Biochem. Ztschr., 1932, **245**, 118–45.
16. A. Morgen, Land. Vers. Stat., 1924, **103**, 1–40.
17. H. Edin Medd. No. 309 från Centralanstalten för försöksvasendet på jordbruksområdet, 1926.

(*Received July 25, 1935*)

Addendum.—Since this paper was prepared, C. J. Watson and W. Godden have published results (this *Journal*, 1935, **3**, 346–50) showing that the rabbit and sheep are not comparable as instruments for determining the digestibility of foodstuffs. The results of our experiment, described on p. 33, thus confirm their findings. S. J. W., E. A. H., November, 1935.

FIBRE-FLAX CULTIVATION IN THE UNITED KINGDOM AND THE EMPIRE

W. H. GIBSON

(Director, The Linen Industry Research Association, Lambeg, N. Ireland)

Introduction.—In the days of the spinning-wheel and the hand-loom the cultivation of flax was firmly established throughout Europe, for this fibre-bearing plant was well suited to European conditions and there were many uses, both domestic and industrial, for linen thread and fabric. At that time all the operations from sowing the seed to weaving the fabric were rural occupations of the farmer and his family.

Many of the old uses for linen remain, some have lessened in importance and other uses have arisen, but, in addition to these influences on demand, the course of English industrial development has had profound reactions upon the use of linen and, in consequence, upon European flax cultivation during the past two centuries.

Within this period, cotton, an imported fibre and thus alien to British agriculture, took first place among the cellulosic fibres of commerce, and goods manufactured from cotton became an important British export.

Such economic trends tended to drive flax cultivation and linen manufacture out of the main stream of agricultural and industrial development during a period of rapid change.

Survival of flax and linen in Ireland.—The survival of flax in Northern Ireland was favoured by the continuance of the system of small family holdings, and by the growth of flax-spinning by machinery, which became a highly specialized industry there.

By a process of slow transition the modern Irish linen industry, operating about one-third of the power-driven spindles of the world, and including all branches up to linen finishing and making up, grew up without losing its association with the Irish farmer, and this interest in local flax supplies preserved flax cultivation in Northern Ireland. Flax thus found a place in the simple crop-rotation of the Irish farmer.

Belgian flax.—Northern France and Belgium produced a high-grade flax crop, and the Belgian flax workers acquired great skill in judging these crops, in taking full advantage of the favourable conditions for retting or steeping flax that were found to exist in the River Lys, and in separating and cleaning the flax from wood and other non-fibrous tissue. Originally used for fine spinning by hand, this high-grade flax came to be used for machine-spinning to fine counts for cambrics and similar goods. In this fine trade Northern Ireland led the way, and became a large importer of Belgian flax. Flax-growing, with a specialized technique, became part of the system of cultivation in this area.

Increasing dependence on Russian flax.—The Scottish coarse-linen industry, which was large and of vital importance in the sailing-ship period, having little home-grown flax, early became a large user of Russian flax. Under the primitive Russian conditions, flax was an attractive cash crop to the peasants and their landlords, so Russia soon

outdistanced all other countries in flax production and became the principal exporting country. The Irish linen industry soon followed Scotland and supplemented its home and Belgian supplies with increasing quantities of Russian flax, which thus became the staple flax in all flax-using countries, its price regulating that of all other flax, whether home-grown or imported. With the growth of the jute industry in Scotland on the foundation of the older flax industry, the Scottish textile manufacturer became still more dependent on imported fibre, so that in the United Kingdom only in Ireland was the complete chain from the cultivator to the linen merchant to be found.

Flax production in Europe.—Over a long period, Russia, by supplying the bulk of European flax, had a depressing effect on flax cultivation elsewhere. In the decade 1862–71, during which Ireland had a peak of flax cultivation in 1864 of 301,693 acres yielding 64,506 tons of flax, the approximate position was as shown:

European Flax in the Decade 1862–71

	Average acreage	*Average tonnage*
Russia	1,500,000	180,000
Belgium and France	300,000	60,000
Ireland	222,000	35,000
Great Britain	20,000	3,500

The Irish linen industry, which consumed 45,000 t., probably used home-grown flax in the main.

The United Kingdom imported 10,000 t. of flax annually from Belgium and 50,000 t. from Russia, the Russian flax going mainly to Scotland.

By the decade 1882–91 the following position was reached:

European Flax in the Decade 1882–91

	Average acreage	*Average tonnage*
Russia	3,000,000	300,000
Belgium and France	200,000	47,000
Ireland	106,000	18,543
Great Britain	3,000	533

At this time, the United Kingdom consumed about 97,000 t. of flax, of which Scotland used about 61,000 t., mainly Russian, and Ireland 36,500 t. The imports from Russia were 60,000 t., and from Belgium 14,000 t.

The figures overleaf, for the period 1909–13, derived from the International Year-book of Agricultural Statistics, illustrate the position immediately before the Great War.

At this time the total requirement of flax in the United Kingdom was about 98,000 t. per annum. The home production was 11,400 t. in Ireland and 100 t. in Great Britain. United Kingdom imports from Russia were 69,000 t. and from Belgium 20,000 t. The average costs per

European Flax 1909–13

	Average acreage	*Average tonnage*
Russia	3,200,000	500,000
Belgium and France . . .	110,000	41,000
Northern Ireland . . .	53,000	11,400

ton of these flaxes for 1909–13 were, Russian £39, Irish £65, and Belgian £81. The Irish flax, intermediate in price and quality, was steadily being supplanted by fine Belgian flax on the one hand, and cheap Russian flax on the other.

Effect of the War.—The European war brought into prominence the important part which linen plays in the supplies of war material. Flax was required in huge quantities for the manufacture of tents, wagon-covers and similar heavy goods, linen thread was wanted for boots and other purposes, and hospital linen was required by the medical services. The progress of aviation and the growth of the Air arm introduced a new use for linen that soon overshadowed all others in national importance, for a fabric made from the finer yarns was found suitable, and became standard, for covering the wings of aeroplanes. The linen industry became fully occupied with the production of such military supplies. The difficulty of securing supplies of flax from the usual sources rapidly became a serious problem. Belgium again became the chief battle-ground of Europe and this cut off supplies of high-grade flax. Although Russia was allied with England up to 1917, war disorganized Russian agriculture and trade, and the difficulty of importing flax and flax seed via the Arctic Ocean was enormous.

In Northern Ireland the acreage in flax increased very little in 1915, was doubled in 1916 and 1917, and was almost trebled by 1918. The chief difficulty met with was in providing increased supplies of seed for sowing. The Northern Ireland farmer was wont to import his seed from the European flax-growing countries, chiefly Russia, thereby simplifying his operations by omitting to save his own seed, often a difficult matter in the Irish climate. The War disorganized flax-growing in Europe, made seed scarce, and importation difficult. It was not easy to get thousands of small Irish farmers to save their own seed satisfactorily. At this time flax cultivation for both seed and fibre was developed in England, but the great fall in prices that occurred soon after the War did not allow the industry to survive.

Post-war trends.—To-day Russia remains the country with the largest acreage under flax, but it has been passing through political and economic changes which render its ultimate position as an exporter of flax difficult to forecast. The area sown to flax in Russia is stated to be about 5 million acres, but the return in fibre appears to have fallen from 360 lb. per acre in the 1909–13 period to 200 lb. per acre in the period 1925–33, the tonnage produced thus remaining at pre-War levels.

Since Soviet Russia to-day aims at agricultural and industrial self-sufficiency, there seems little prospect that she will expand her production in order to increase her exports. A small margin of flax for export

at high prices may be thought more profitable, particularly as this may, at the same time, place the newly developed Russian linen industry in a favourable position, when compared with foreign linen industries depending upon Russian supplies.

The growth of Russian industry appears to be reducing the importance of Russia to western Europe as a supplier of primary products, such as wheat or flax. Russian industries are supplying their home market more and more with goods made from native primary products, and, if foreign markets can be secured for Russian manufactured goods, this course will be preferred to maintaining exports of raw materials. The trade returns are significant. They show that about 280,000 t. of flax were exported by Russia out of a production of 500,000 t. annually during the 1909–13 period, but with production again reaching 500,000 t. the average export was only 55,000 t. in the period 1925–9 and about 80,000 t. in the period 1930–3. This points to an increased consumption of flax in Russia itself of 200,000 t., i.e. over 80 per cent. of the entire Russian output is used at home. The shift of production and trend of prices are shown below (figures from the International Institute of Agriculture):

World Production and Prices of Flax

Period	*Production (1,000 metric tons)*		*Price of ZK Livonian £ per ton in London*
	U.S.S.R.	*Other countries*	
1909–13	513	228	35½
1925–9	298	233	86
1930	440	190	51¼
1931	550	134	35¼
1932	500	98	45½
1933	560	128	51¼
1934	530	165	61

The broad picture is that before the War Russia produced more than two-thirds of the world's flax but used less than one-third.

During the years 1925–9 Russia used as much of her own flax as before the War, exporting the remainder, only one-fifth of the pre-War exports, at a high price. In the same period and in response to the same price-level, the rest of the world returned to its pre-War level of flax production, and the world outside Russia used about 290,000 t. of flax, drawing only about 60,000 t. from Russia. The increase in Russian production, although Russian exports increased only to 80,000 t., coinciding with the world crisis, oversupplied the flax market and forced down the flax production of other countries to a minimum of 98,000 t. in 1932. Although the production of the rest of the world has increased since 1932, this seems to be partly due to the limited export and greater retention of flax by Russia. Russia is now producing more than three-quarters of the world's flax and using two-thirds of it. Although the quantity of Russian flax exported is low enough to maintain flax prices, it is still imported to such an extent into the United Kingdom that it forms the chief source of supply. Unless home supplies of flax can be permanently

increased, the British linen industry will be too dependent on imported flax to benefit fully from the relative increase in popularity of flax as a textile fibre, which has been largely brought about by British industrial enterprise.

It is clear from the history of flax cultivation in the United Kingdom that a renaissance of flax-growing in Northern Ireland and Great Britain is the first condition necessary to establish home supplies of flax on an adequate and permanent foundation.

Post-War position in Northern Ireland.—During the decade 1921–30, in conformity with the general situation, the area under flax in Northern Ireland settled down to 33,000 acres, but when, in the general crisis, flax fell from £80 to £42 per ton in 1930, at this unremunerative level the area cultivated fell to 7,440 acres in 1931, 6,093 acres in 1932, and, with recovery setting in, 9,784 acres in 1933, 15,676 acres in 1934, up to 27,755 acres in the present year.

Attitude of the Irish linen industry.—In general, the dependence of the industry upon foreign supplies has been viewed with concern by the trade, and trade organizations have existed to foster home flax production for nearly a century. With the formation of the Linen Industry Research Association in 1919 under the auspices of the Department of Scientific and Industrial Research, the problem of the scientific development of home flax supplies was placed in the forefront.

By continuous research upon the economic botany of the flax plant and upon methods of fibre-extraction, it has been sought to place the home growers of flax in a relatively advantageous economic position. Such work will justify itself if it results in the establishment of a stabilized area of flax production in Great Britain and Northern Ireland of real significance as a source of supplies to the linen industry, rendering it less sensitive to price fluctuations brought about by variations in foreign supplies.

The Linen Industry Research Association and flax cultivation.—The main work of the Linen Industry Research Association is concerned with the manufacturing processes of the linen industry, but the association of research on flax cultivation with such work, rather than its independent prosecution by a purely botanical or agricultural organization, has had several advantages. The produce of the plant, in this case the flax fibre, having no direct application in farming, and being hidden within the stem of the plant, the value of the crop is not apparent to the unpractised grower, and the requirements of the linen industry may not be understood by him. The linen industry in N. Ireland, as the principal producer of fine linen, must have supplies of flax of fine and medium qualities, so research has been directed towards securing the production of these qualities at home, while reducing the costs of production to a minimum by mechanizing the methods of cultivation and fibre-extraction.

Pedigree seed.—The first requirement was the origination of pure lines of fibre flax to give uniformity in the plant, and hence in the fibre, and at the same time to give an increased yield in fibre per acre to the grower. So long as the Irish or British flax grower has to use sowing seed imported

from eastern Europe, he is in the same position as these producers of cheap fibre in regard to seed, and has only better cultivation to set against their low costs due to differences in the standard of living. Under the auspices of the Development Commission, J. V. Eyre began systematic work on flax selection before the War, which he continued as Director of Research for the Linen Industry from 1919 to 1926.

At first, since tallness of the plant was found to be an heritable quality, pure lines were originated from single selected tall plants. By 1930 the seed of this type, known as 'J.W.S.', originated by Dr. Eyre in 1911, had reached 650 t., or enough to sow 15,000 acres. This seed increased the yield per acre to the farmer by about 30 per cent. over the yield got from current commercial brands of sowing seed. For the linen trade this tall variety of flax had two disadvantages, the excessive length of the fibre strands gave difficulty with the mill machinery, and these strands were inclined to be coarse.

Meanwhile, A. G. Davin and G. O. Searle were investigating by statistical and other methods the inheritance and interrelationship of the principal characters of the flax plant. A method of estimating the proportion of fibre in the stem was worked out, in which the percentage area of fibre in a perfect cross-section cut half way up the stem, was measured on the magnified image of the section. It was found that four characters of the plant—length of stem, percentage of fibre, time of flowering, and number of seeds per capsule—were heritable. Accordingly, selections were made for high fibre-content as well as length of stem.

Plant-breeding on these lines involved much time and labour; in the case of one variety alone, 7,864 plants were measured for length of stem and 762 of these were sectioned before the selection of the single plant, which was to be the founder of the line, could be made. In this way the Liral series of flaxes, some of which are now available commercially, was originated. They have been included in official variety trials by the Ministry of Agriculture, Northern Ireland, for about ten years in some cases, and the advantage to the home flax grower can be realized from the following table:

Normal Yield of Flax Fibre per Acre

Variety	*Yield in stones (14 lb.)*
Commercial seed	30
J.W.S.	40
Liral Beatall	51
Liral Monarch	47
Liral Crown	48
Liral (unnamed)	58

Although the limit of increase in yield may now be in sight, research on heritable characters and selection based upon it can still provide strains to suit climatic and soil conditions and to give fibre of good quality. Besides this, re-selection and re-establishment are desirable after a strain has been in commercial use for some years.

Seed-bulking.—After any pedigree strain has been originated, it is necessary to establish some means of raising the bulk of the seed to a commercial quantity while maintaining the purity of the strain. Conditions in Northern Ireland, where flax-growing is undertaken by thousands of small farmers who are not accustomed to save seed, render it unpracticable to establish an organization for this purpose there.

It is not remunerative in the United Kingdom to raise fibre flax for seed only, so it has been found necessary to introduce the cultivation of fibre flax into Great Britain under the most favourable conditions for saving the seed and also securing a good quality of fibre. This was attempted, at first in Somerset, a central flax factory, closely following Belgian practice, buying flax crops from the growers and working them for seed and fibre. This factory succeeded in its principal object and established the commercial bulk of J.W.S. seed, which was sent in some quantity to various parts of the Empire, and later that of Liral Monarch, but the crops were not of Belgian quality, and the costly Belgian methods were not justified by the quality of the fibre obtainable. It was realized that extensive research work on the processes for obtaining seed and fibre from the crop was required, and in 1929, with the assistance of the Empire Marketing Board and the Government of Northern Ireland, an experimental flax factory was set up at the Research Institute, Lambeg, Co. Antrim.

The Belgian methods of handling flax were studied systematically with the object of retaining all the operations which appeared to be advantageous to the final product, but these processes were mechanized where possible, thus reducing the numerous and costly handlings of the material to a minimum. As a result of this work, the present position has been reached.

Operations in a modern flax factory.—The first operation, de-seeding the flax straw, is done by the process of 'rippling' or combing off the seed-bolls, as this method does not injure the straw or the seed. A de-seeding machine, embodying this principle, has been designed and constructed in which power-driven combs enter progressively deeper into the head of a layer of flax straw fed past the combs by means of a conveyor-belt, the throughput being 5 t. per day.

The seed-bolls are broken and conveyed without further handling to standard seed-cleaning machinery. The seed is then put through a simple seed-dryer, resembling the grain-dryers used in Canada; the seed then keeps without serious loss of germination until it is required for sowing next season, provided the storage is also dry.

The retting or steeping remains a bacteriological operation, but is done in large concrete tanks, holding 3 or 4 t. of straw, under controlled conditions of temperature, water-flow, and water-change. In Belgium the best straw is given a double retting in the River Lys, with an intermediate drying, but owing to the greatly increased handling, this is costly.

Drying after retting is best done in the open air; the bundles of straw are unrolled against a simple fence-work on the drying-ground, and drying is rapid, even in wet weather. The labour of opening the bundles for drying is also minimized. The best method of disposal of retting-effluent

is by irrigation over suitable land. Retting, by dissolving away non-fibrous connective tissue, loosens the fibre strands from the wood of the stem. The dried, retted straw is then passed through a breaker, to break the wood into short lengths. Fluted roller breakers of the usual type were investigated, but were discarded in favour of a new type of breaker, termed a lateral breaker, in which the layer of retted straw is fed continuously, the straws lying at right angles to the direction of feed, and being broken by parallel oscillating bars during their passage through the machine. Broken straw from this breaker can be picked up automatically by the belt-feed of an automatic scutching machine of the turbine type. The broken wood is knocked out in its passage past rotating blades in a cylindrical casing, and scutched fibre, i.e. fibre free from wood, is delivered at the end of the machine. A certain amount of tow, short fibre, is removed with the wood, and this is carried along on a conveyor-belt to a tow-shaker or separator, the wood and dust falling through a grid and being removed from the building by a dust-extraction plant. Owing to the improved methods of handling the straw and maintaining the parallelism of the stems, the proportion of tow is much reduced.

Location of central flax factories.—A centralized method of handling the flax crop for seed and fibre, such as this, should be established only in districts where conditions are favourable. In the first place the district must enjoy a climate, particularly at harvest, which favours seed-production as well as fibre. It is also desirable for fields to be large and fairly flat, favouring the adoption of mechanical pulling, instead of hand-pulling, at harvest. It is an advantage for a central factory to be able to draw its crops from a small number of large farmers, who are using modern mechanized methods of arable farming. With the use of pedigree seed, the factory should then receive large tonnages of flax crop highly uniform in quality, which can be given the most suitable treatment in retting and scutching. The eastern counties in Great Britain are most likely to possess these advantages, and the Linen Industry Research Association has begun to develop flax growing for pedigree seed and fibre there.

Experiments in Norfolk.—In 1931 H.M. the King was graciously pleased to have an experiment made with 3 acres of flax on the Sandringham estate. This gave the good yield of 40 stones to the acre, and afforded preliminary estimates of the costs of cultivation, fibre production, and value of the products.

The crop was transported to Northern Ireland and worked in the experimental flax factory there. The general result was so promising when compared with previous experience in Great Britain that arrangements were made for large-scale trials. The first of these was carried out in 1933 with a crop of 120 acres. The whole of the crop was baled in Norfolk and transported to the experimental factory at Lambeg, Northern Ireland, where it was de-seeded and processed for fibre under strict factory conditions. The broad result of the factory working was the production of 24 t. of flax fibre, which was sold for almost £2,000, over 12 t. of tow realizing nearly £300, and about 27 t. of seed realizing about £1,000. The flax growers received nearly £1,200 from the factory in

payment for crop, and omitting the baling and transport costs, the total costs were estimated to be about £3,000. A second large crop was grown in Norfolk in 1934, and 265 acres were planted in 1935. These crops have not been transported to Northern Ireland, but will be processed in a modern flax factory in Norfolk under the auspices of Norfolk Flax, Ltd., a private company formed for the purpose, the capital for which has been provided by firms in the linen trade.

The 1934 crop was de-seeded in Norfolk and the de-seeded crop stored; the de-seeding of the 1935 crop is proceeding, and the factory is now ready to carry on retting and scutching operations. In 1934 the drought injured the crop from the farmer's point of view, but in 1935, although conditions were again dry, with better selection of land and rather more favourable incidence of rainfall, an excellent crop has been secured, showing the good average return of 1·9 t. per acre to the grower. There is every reason to believe that the 1935 crop will yield an excellent supply of pedigree seed, and fibre of Belgian quality commanding a good price in the Belfast market.

Prospects in Eastern England.—Under present conditions the Norfolk flax factory could continue to pay attractive prices to the farmers and the area of flax in Norfolk and the Eastern Counties could be expanded very considerably. Expansion for this enterprise depends upon the market for pedigree flax seed in Northern Ireland. At present, flax prices are attractive and, if maintained, the Northern Ireland farmer would increase his acreage, particularly if he could be certain of obtaining supplies of pedigree seed from Norfolk or other suitable flax-growing areas. Even without much expansion in Northern Ireland, about 2,000 t. of pedigree seed would be needed to sow nothing but pedigree flax there, and an area of 10,000 acres of flax, worked on the central factory system to supply both seed and fibre, would be required to produce 2,000 t. of seed annually.

It would not be difficult to increase the acreage under the crop and, concomitantly, the facilities for de-seeding, but to extend the facilities for retting and scutching would require considerable constructional work and capital expenditure.

At the present time much interest is being shown in methods of fibre-extraction that would be alternative to bacteriological retting. The development of any method which would render retting unnecessary in the district where the flax is grown would simplify the central flax factory and facilitate expansion.

Research programme in England.—It must be emphasized that successful operation depends upon cultivation resulting in a crop which, as harvested, contains flax fibre of good quality in good yield, and upon fibre-extraction processes that are economical and not harmful to fibre quality. To ensure these conditions as far as possible, the Linen Industry Research Association has formed a branch Flax Research Institute at Flitcham Abbey, near King's Lynn, to which it has transferred its botanical and agricultural staff. This will enable Norfolk flax growers to get constant and prompt technical advice on flax cultivation, and the central flax factory to get technical advice and assistance on the problems

of de-seeding and fibre-extraction. The Flax Research Institute will study, under Norfolk conditions, such matters as suitability of soils, crop-rotations, manures, weed-killers, cultivations, and harvesting methods, besides continuing plant-breeding work and the establishment of improved strains of flax. In this way we may endeavour to equal and then surpass the products of Belgium and Northern France and establish the flax crop on its merits in the Eastern Counties.

Flax in Northern Ireland.—So long as we regard flax cultivation in Great Britain as a means of ensuring a supply of pedigree seed to Northern Ireland, the area of flax grown in Northern Ireland must always be at least four times as great as that grown in Great Britain, and Northern Ireland flax will be the principal home supply of flax fibre.

Mixed farming predominates and farms are small in Northern Ireland. To a large extent the holdings are self-contained and subsistence husbandry has not been displaced by purely commercial farming. For example, though a proportion of the potato crop is exported, much of this crop is used on the farm for food or fed to live stock. A good deal of the eggs, butter, milk, poultry, and meat is also consumed on the farms. Forage or green crops are grown, and there is a large production of hay to supply winter keep for the large numbers of cattle reared. In 1914 the areas of the principal crops in Northern Ireland were, in acres: oats, 334,846; potatoes, 170,225; turnips, 58,567; and flax, 40,580; in 1934 the areas were: oats, 279,789; potatoes, 137,321; turnips, 35,960; and flax, 15,676.

Flax is grown in an eight- or nine-year rotation, such as, roots, oats, hay, pasture, pasture, pasture, oats, flax; this safeguards against retention in the soil of the organisms of flax-wilt and other diseases. Since oats occur twice to flax once in this rotation, it may be supposed that flax could be increased in Northern Ireland to about half the area under oats, i.e. to 160,000 acres, without introducing any radical changes in agricultural practice.

The area of flax or any crop grown by the individual farmer is small, not more than one or two acres, and even in these there may be considerable soil variation. The Irish farmer now fully realizes the advantages which pedigree flax seed gives him, and how these advantages are secured without any changes in his existing practice. Any sudden changes in Irish flax cultivation could not be expected, but a systematic endeavour could be made to get the best out of the existing individual system by a careful study of the data of cultivation, leading to a classification of soils as to their suitability for flax, comparison of crop-rotations, incidence of weeds, and so on. The small Irish flax crops are all harvested by hand-pulling, and are usually steeped at once by the farmer himself in a flax dam, dug by a convenient stream. The suitability of the water in retting-dams varies enormously all over the country, and a difference in the water can make large differences in the value of the fibre from crops starting on level terms as pulled. A classification of available retting-waters to enable the best use to be made of them is highly desirable, and they could be used under less primitive conditions with proper means of effluent treatment.

After drying his retted flax straw, the Irish farmer takes it to a scutch-mill, where for a fee the flax fibre is extracted from the wood. The flax breakers and scutch-wheels are primitive machines, and it is probable that through research work better machines could be made available to improve both the yield and the quality of the flax fibre. Since the Irish farmer sells his own flax fibre, any improvement in scutching facilities is important to him. The provision of pedigree seed and of advice and assistance to the Irish farmer on the above lines should lead to a progressive development of Irish flax-growing, and call for a corresponding development in the Eastern counties in Great Britain to provide the supply of seed.

Empire flax.—The development of flax-growing in other parts of the British Empire is a further possibility that should be kept in view. The experience gained on the broad acres of Norfolk, where farming is highly mechanized, would seem to be readily adaptable to conditions overseas.

There should be no insuperable difficulty in the way of the British Empire supplying the world, outside Russia, with flax, and the home country growing a large proportion of the flax required by our own linen industry, if full advantage be taken of the results which systematic industrial research now provides.

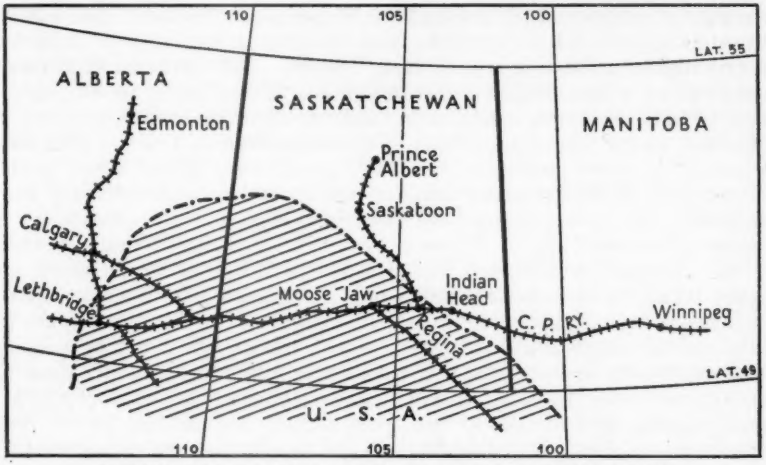
(*Received October 14, 1935*)

TREE-PLANTING IN THE SEMI-ARID AREA OF CANADA

NORMAN M. ROSS

(Tree-planting Division, Dept. Agriculture, Canada.)

THE greater portion of the southern sections of the prairie provinces of Manitoba, Saskatchewan, and Alberta may be classed as semi-arid, for the average annual precipitation of snow and rain in these areas varies from 11 to 18 in., over a 20-year period. Temperatures will run as high as 105° F. in the shade in summer to −55° F. during winter. Spring usually starts the first week in April, and the ground generally freezes



SKETCH MAP OF CANADIAN PRAIRIE PROVINCES

The shaded area is most subject to extremes of drought.

in the first week in November. Precipitation during the growing-months from April to July will average about 9 in. in normal seasons. Seasons, however, are not always normal. We have just experienced four or five years of extreme drought.

It can be seen readily that climatic conditions are not favourable to tree-growth on the Canadian prairies. If we could be assured of 15 to 18 in. precipitation each year, tree-planting would not be a serious problem, but extreme and sudden changes of temperature and periodic recurrence of seasons of excessive drought present real difficulties to the planter.

Generally speaking, the soil throughout the prairies is rich in plant-food, and, given adequate moisture, it supports a heavy growth of native grasses and other perennial vegetation, against which trees have to compete. During seasons of poor rainfall the native vegetation persists and uses up so much moisture that a growth of trees cannot be successfully maintained on the same ground.

The prairie tree-planter, then, has to contend not only with unfavourable climatic conditions, but also with competition from the natural ground-cover. Experience has shown, however, that even in the driest areas trees suitable for shelter-belts, and also for the production of fuel and of fence-posts, can be grown if proper methods are adopted.

First of all the soil must be thoroughly prepared in order completely to eradicate the native grasses and other perennials, and to store up a reserve of moisture to give the young plantation a reasonable start. This usually requires two seasons. In the first season the sod is broken a few inches deep and then thoroughly worked. One season is sufficient to kill all the native plants. The following year the land to be planted is deeply summer-fallowed to open up the soil for the roots and to conserve moisture.

The next step is to select varieties that have been proved hardy and capable of withstanding drought when once established. The list of varieties suitable for shelter-belts, and for propagating in large numbers at reasonable expense, is very limited. It consists of: Caragana (*Caragana arborescens*), a leguminous shrub of Russian origin, exceptionally hardy and drought-resistant, which makes a dense shrubby growth to a height of about 20 ft.; Manitoba Maple (*Negundo aceroidis*), a native tree with a somewhat bushy tendency, which will grow to a height of about 40 ft.; Green Ash (*Fraxinus lanceolata*), a native, rather slow-growing tree, also very drought-resistant; the American Elm (*Ulmus americana*), a hardy native tree; native White Spruce (*Picea alba*); Colorado Spruce (*Picea pungens*); and Scotch Pine (*Pinus sylvestris*), of which there are many types, the one most suitable being propagated from seed secured in Finland or central Sweden. All these varieties can be grown successfully on the average upland prairie soils. In certain districts, usually associated with lighter soils, the water-table may be reasonably close to the surface (from 7 to 15 ft.), and in these districts many varieties of poplars and willows, in addition to the trees already mentioned, prove very satisfactory. The following figures of height-for-age confirm this statement:

Height-growth of Various Species from Measurements made at Indian Head, Saskatchewan

Variety	*At 10 years old*		*At 20 years old*	
	ft.	in.	ft.	in.
Manitoba maple . .	17	0	27	8
Green ash . . .	10	6	22	6
American elm . .	8	6	19	2
Paper birch . . .	17	0	28	0
Russian poplar . .	25	0	47	0
White spruce . .	3	0	16	4
Scotch pine . . .	8	0	22	6
Jack pine . . .	7	9	21	2
Lodgepole pine . .	5	8	20	1
Tamarack . . .	14	0	28	0
Siberian larch . .	15	0	31	9

Up to the present, tree-planting on the prairies has been confined

principally to establishing shelter-belts and wind-breaks around the farm homes, gardens, fruit plots, and stables. Very few plantings have been made for the production of fuel or other wood materials.

These shelters usually consist of from two to ten rows of trees, and, in order to get benefit from them as early as possible, they are planted close together, i.e. about 4×4 ft. apart. This spacing is wide enough to allow cultivation between the rows for about three years, a period during which weeds must be kept from going to seed, and great care taken that grass does not become established. After about three years, growth will be sufficiently dense to cover the ground and shade out the natural vegetation. To prevent grass working into the belt from the outside, it is very important to keep strips of soil, at least 16 ft. wide, continuously cultivated along both inner and outer edges of the belts; these cultivated strips also provide a wide area for the feeding-roots and for the conservation of moisture.

In the districts most subject to drought it is almost impossible to start plantations during dry cycles, and therefore every advantage should be taken of seasons with normal rainfall to get the young plantations well established. Once they are established, belts of hardy varieties will stand up under very severe drought conditions.

The soil in the prairie provinces is particularly adapted to the production of wheat of the very highest quality, and this is the principal crop produced on the farms. For the production of wheat enormous acreages are under cultivation that are entirely open to the full sweep of the winds. Constant ploughing and cultivating for many years has worked out the natural fibre in these soils and has rendered them very susceptible to drifting. This condition is particularly aggravated during seasons of light winter snowfall and sparse rainfall. It is now not an uncommon experience for farmers to have the seed entirely blown out of the soil before it has a chance to germinate, or, even after germination, to find the young crop completely cut off or buried by the drifting soil.

The tendency for the soil to drift, coupled with the drought-hazard, has become an extremely serious problem and is causing the Government and those dependent on agricultural prosperity very considerable concern. Many remedies have been suggested; among others the planting of shelter-belts to protect field crops has been very widely discussed of recent years.

Unfortunately the problem is a comparatively new one and but few data are available at present to indicate whether shelter-belts might have the desired effects of checking soil drifting and conserving moisture, and, if so, whether such belts can be maintained economically. In certain cases, however, where a few individual farmers have already planted and established rather short stretches of field shelters, the results have been encouraging: the crops within the influence of the belts have shown decided increases in yields, and in some instances have been saved from soils drifting in the spring. It remains, however, to be determined whether a more general planting of crop-shelters will prove practical and profitable over larger areas. This will entail cutting up fields into smaller units of probably 40 to 80 acres, which, however, some farmers

think too small for the economical operation of the larger types of farm implements that are at present in general use.

Considerable sums of money have now been voted by Parliament to assist farmers in securing water-supplies, and in introducing new methods which, it is hoped, will ameliorate drought and soil-drifting conditions in the future. Part of this money will be spent in encouraging the systematic planting of field-shelters over comparatively large blocks, including several adjoining farms for demonstrational purposes. It is hoped that after a few years such demonstration areas will prove whether projects of this kind are economically sound or not.

In the meantime steps are being taken to increase the production of nursery stock on the two Dominion Forest Nursery Stations, from which over 150 million seedlings have already been distributed for the further encouragement of planting farm shelter-belts. The protection of vegetable gardens and fruit plots, although of vital importance in helping to make the farm a self-sustained unit, is not the only benefit derived, for in a territory that is almost devoid of natural tree-growth the aesthetic value of these shelter-belts in improving the amenities of the homestead is of equal if not of greater economic importance.

(*Received August 6, 1935.*)

PASTURE STUDIES VIII. IMPROVEMENT OF GRAZING LANDS IN EASTERN CANADA

L. C. RAYMOND

(*Assistant Professor of Agronomy, McGill University, Macdonald College, Quebec*)

WITH PLATE 6

Introduction.—Eastern Canada comprises that section of the Dominion lying east of the Great Lakes and is divided into the five provinces of Ontario, Quebec, New Brunswick, Nova Scotia, and Prince Edward Island. It represents a total land area of 630 million acres, much of which is quite unsuited for agriculture, either because it is rough and rugged or its climate, in the northern parts, is quite unfavourable. Whereas the area of possible farmlands amounts to some 130 million acres, the portion at present occupied is approximately 49 million, of which slightly over 8 million are devoted to pasture.

Measured in terms of many European countries the whole of Canada is of recent settlement. The early settlers engaged extensively in lumbering, and it was not until the past century was well advanced that any great measure of permanent agriculture was established. Thus very few farms will be found where anything approaching intensive farming operations have been carried on for more than one hundred years.

As the forests were cleared away, the first use made of the land was for permanent pastures. Following the removal of the lumber, fire was employed to get rid of the brush, when the land was either left to seed itself naturally, or a sparse application of grass and clover seeds was scattered in the ashes. The ease of breaking up such lands eventually determined whether they would be utilized for cropping. Many fields that have never been broken, or only roughly cleared, exist in eastern Canada to-day, representing the great bulk of the so-called permanent pastures.

Until the past fifteen or twenty years, little thought was ever given to the pasture area beyond measures calculated to keep down tree and shrub growth. Even yet, on permanent pastures, it is quite the exception to find any well-ordered practice of fertilization and management. The impetus for the present interest in pastures is dictated in part by the favourable results obtained in other countries through the use of fertilizers, coupled with proper management, and in part by the very apparent falling-off in productivity of our grazing areas.

Space will permit only of a generalized discussion of the subject under review. Results of experimental work are still largely unpublished and therefore cannot be given. The phases dealt with most fully will include the natural features of the region, the animal population, types of pasture, and the organization involved in pasture-improvement work, together with a statement of the important projects that are under way.

Natural Features of the Region

Soils.—The soils of eastern Canada present a tremendous range in type. Practically all are of glacial origin, but they have been greatly

modified, through the centuries, by the many and diverse natural agencies affecting them.

Only a fair beginning has been made with systematic soil surveys. Both in Ontario and Quebec surveys have been made, but in each case they are concerned with specialized soil types, so that the information at present available does not warrant any attempt at definite zoning of any large territory.

The accompanying map (Fig. 1) is designed to present some idea of the major soil divisions and their location. For the provinces of Ontario and Quebec it is based on the genetic soil map of Canada, as prepared by the soils group of the Canadian Society of Technical Agriculturists. For the three Maritime Provinces the boundaries given are purely empirical, since no soil data are available. The four soil divisions represented on the map are:

1. Laurentian Upland Podsols.
2. Appalachian Upland Podsols.
3. Brown Forest.
4. Marine, Lake, and River.

The Laurentian and Appalachian podsols have a number of features in common. They each display the typical leached layer characteristic of true podsols; they are acid in reaction, and their upper layer consists of organic matter only slightly decomposed. Whereas fairly extreme acidity is found in each case, the lime-content of the former is notably higher, in spite of the fact that the Laurentians are not considered as fertile as the Appalachian. Laurentian podsols are formed from igneous rock, but the Appalachian are from sedimentary. A forest-cover of deciduous trees is found in the virgin lands of both areas.

The Brown Forest [1] soil regions are much less extensive than the podsols and represent a more fertile agricultural soil. Although these soils have undergone considerable leaching, they do not present the distinct ashy layer characteristic of the podsol. The iron, aluminium, and organic matter are fairly evenly distributed through the weathered mass of soil. As may be implied, their colour is a brownish hue, and the change, in this respect, is slight with increasing depth. In reaction they are neutral to acid, but, as a group, would generally be described as mildly acid.

The fourth group, designated Marine, Lake, and River soils, is a very diverse one, varying all the way from an almost purely organic to an inorganic colloid type. Thus they include mucks, gravels, sands, clays, and mixtures thereof. They are naturally associated with the watercourses of the country and frequently occur as long narrow strips bordering lakes and rivers. Muck soils are widely distributed, in areas varying from one to several hundred acres in extent. Although the total area belonging to this division is not large, some of the most productive farming districts are found within it.

Our detailed knowledge of these soils is too meagre to give much idea of their composition. In general, one may say that in the cooler parts the nitrogen-content is extremely high but in a very inactive state.

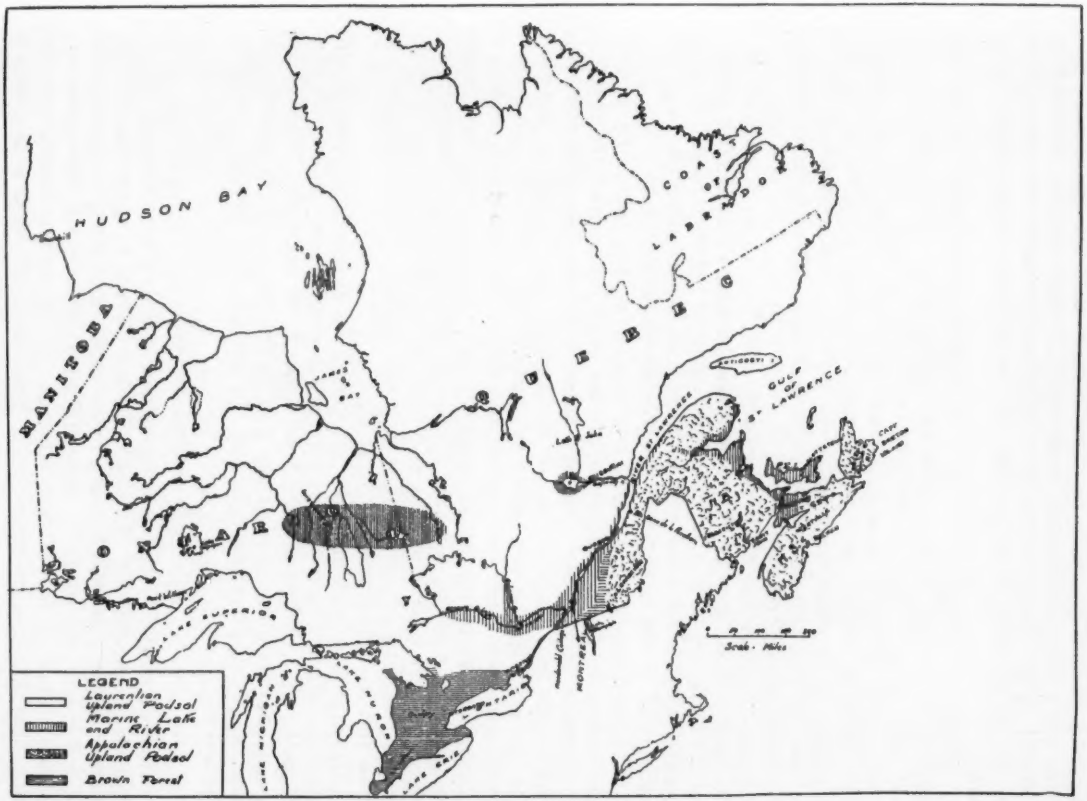


FIG. 1. Map of eastern Canada showing the main soil zones and the location of the stations referred to in the text.

Phosphorus is almost invariably a limiting factor in most soils of eastern Canada. Potash is usually present in fairly adequate quantities. Acid soils are widely distributed, particularly in those sections with a high rainfall. Limestone, in outcrops of high quality, occurs over most of this region, at intervals which permit of its use without undue transportation costs.

Climate.—The climate of eastern Canada presents some very decided pasture problems. Temperature and precipitation figures show a considerable range, varying generally from east to west, with cooler and more moist summer seasons prevailing under maritime conditions. Extremes of 100° F. or over are not uncommon in parts of western Ontario, but a much lower and more even temperature is characteristic of the Maritime Provinces and parts of Quebec. Precipitation figures—a combination of rain and snowfall—vary from 29·42 in. at Chatham in Ontario to 43·24 in. at Charlottetown in P.E.I., as an average for the ten-year period 1925–34. Particularly in the east, a considerable portion of the total falls as snow. The distribution of summer rainfall is fairly similar to that for total precipitation, but its effectiveness is greatly influenced by the high evaporation in the warmer sections.

The pasture season is one of four or five months, beginning in some sections early in May and in others not until June, and terminating in September or October. Seasons affect both the time that pasturing may begin and the evenness of herbage-growth throughout the year. In the early spring the nights are usually very cold, and productive stock that have been well housed and highly fed will shrink unduly if exposed to such conditions; even though the grass may have made considerable growth. After the long winter of inactivity, herbage-growth develops very rapidly in May and June, but is severely checked, in the warmer sections, by drought in July and August. This is followed by a second but minor peak in September.

Climate thus presents some real problems in handling pastures efficiently. Management aspects are greatly emphasized under such conditions. A well-grazed sward is difficult to maintain. Midsummer shortage must in many places be met by growing supplementary crops, and is generally overcome, in part, by grazing the aftermath from the meadows.

The Animal Population

Some account of the grazing-animal population will be of aid in visualizing the existing situation. Table 1 shows, in approximate numbers, the totals of milch cows, other cattle, and sheep, by provinces, together with the totals for eastern Canada and for the Dominion as a whole. Data are included in the table giving, by provinces, both the occupied and possible farm land. Some idea of the concentration of stock is made possible by a study of these figures.

Types of Existing Pastures

The acreage under pasture in the five eastern provinces, as shown in Table 2, is between one-sixth and one-seventh of the area of occupied

TABLE 1. *The Population of Grazing Animals for Eastern Canada in detail and Totals for the Dominion. Figures on available farm land to admit comparison* (1931)

				Acres of Farm Land	
	Milch cows	*Other cattle*	*Sheep*	*Occupied*	*Percentage of possible occupied*
P.E.I. .	44,000	55,000	76,000	1,191,000	96
N.S.. .	108,000	113,000	195,000	4,302,000	65
N.B.. .	101,000	113,000	143,000	4,153,000	42
Que.. .	836,000	884,000	732,000	17,758,000	36
Ont.. .	1,098,000	1,339,000	1,035,000	21,978,000	39
Total .	2,187,000	2,504,000	2,181,000	49,382,000	42
Canada .	3,513,000	4,478,000	3,608,000	162,516,000	30

(From *Canada Year Book*, 1932)

TABLE 2. *Acreage devoted to Pasture in the Five Eastern Provinces as an average of the years 1930–4*

Prince Edward Island	221,018
Nova Scotia	770,184
New Brunswick	507,100
Quebec	3,213,820
Ontario	3,019,495
Total	7,731,617

farm land. The available statistics do not provide any information as to the kinds of pastures that are included in this total, nor is any precise information on this point obtainable from any other source. It will only be possible, therefore, to note the kinds of pastures that exist and give but a vague idea of their relative importance.

In the sense in which the term is used in the older countries, permanent pastures may scarcely be said to exist in Canada. The term is used with reference to rough areas, where the cost of breaking and seeding is, for the time being at least, prohibitive. They might much more logically be referred to as natural pastures. The total pasture area, as recorded in the table, may then be divided into two: those areas on tilled land which are used only temporarily for this purpose, and the natural pastures. Of the two, the latter occupies much the larger area.

Tilled pastures.—Tilled-land pastures are of the same general type throughout but vary somewhat in the herbage species seeded. They are almost always fields that have been used for hay-production for one or two years after seeding. The common practice is to break the sod and plant to a hoed crop, which is followed by grain and seeded down. After one or more years of hay, from one to four years of pasturing may follow. The mixtures of herbage plants used in seeding-down consist largely of timothy, red clover, and alsike in those districts where acidity is fairly high; this is modified where soils are less acid by the inclusion of alfalfa and a corresponding reduction in the amount of the other

legumes. In the absence of alfalfa in the mixture, the legumes are usually entirely absent by the time the pasture years are reached, and the sward is made up very largely of timothy. Depending on the district, the stand may become modified by the incursion of some of the common pasture types, such as red top, Canada or Kentucky blue, and wild white clover. In those districts where alfalfa can be grown, a much more useful pasture can be obtained, since this legume is longer-lived. It is exceedingly useful also inasmuch as its deep-rooting habit permits its continued growth during dry periods when few other herbage plants will make any contribution.

Pure stands of alfalfa are used to a limited extent in western Ontario for pasture. Sweet clover is also worthy of mention. It is used, however, more as a supplementary crop, the biennial form being planted in the spring and utilized for grazing in July and August of the same year. In some districts orchard grass is included, particularly in combination with alfalfa.

There is a slight but growing tendency to seed down with a combination mixture which, in addition to the more strictly hay species, includes some Canada or Kentucky blue, red top, and white Dutch clover. The use of wild white clover in a seeds-mixture can hardly be said to have begun.

Supplementary crops, such as maize, oats and peas, millet, and a variety of other annuals, are grown in those sections where the summer droughts are likely to be most severe. Closely associated with these is the practice of grazing the aftermath from the hay meadows. The hay crop is removed in June or early July, so that in early August the legume-hay meadows in particular furnish considerable grazing.

The direct fertilization of tilled pasture lands is not at all common. The hay meadows are quite commonly top-dressed with barnyard manure, and some residual effect carries over into the pasture period.

Natural pastures.—Natural pastures vary tremendously in their make-up and usefulness. On the one hand, there are areas so stony and rough that little opportunity is afforded for a sward to develop. A wise policy would have left such lands possessed of their native trees. These shade, on the other hand, into another class, still unproductive, where large moss hummocks (largely *Polytrichum spp.*) take possession of at least half the surface, and where hard-hack (*Spirea tomentosa*) still further crowds out species suitable for grazing. Possibly fifty per cent. of these pastures, however, provides sufficient opportunity for sod-formation and the growth of useful herbage to warrant some kind of treatment for their improvement.

Although comparatively little is yet known in any precise way about the characteristic species association on these natural pastures, a beginning has been made. On the podsols, where the acidity is relatively high, the dominant species is bent grass (*Agrostis spp.*). The order of the other common grass species is quite variable, but will most commonly be Kentucky blue (*Poa pratensis*), timothy (*Phleum pratense*), and red fescue (*Festuca rubra*). Wild white clover (*Trifolium repens*) is very widely distributed in associations of this type. A very common weed

grass in such districts is poverty grass (*Danthonia spicata*), found growing in high, dry, and infertile locations. The most prevalent pasture weed, particularly in the Appalachian podsols, is hawkweed, either the orange- or the yellow-flowered species (*Hieracium aurantiacum* or *H. florentinum*).

The species found on the brown-forest soils vary as between the east and the west. This is probably a climatic influence. In the more easterly region about the only difference found, as compared with the podsols, is a somewhat greater proportion of Kentucky blue, and a corresponding decrease in the poverty grass and hawkweed. To the west the proportion of Kentucky blue becomes much greater and that of the wild white clover distinctly less.

On the marine, lake, and river soils, and more particularly the heavier soils found in this group, Kentucky blue is usually the outstanding species. In some districts Canada blue (*Poa compressa*) takes the place of Kentucky. Wild white clover is not present to anything like the extent that it is on the higher and more acid soils.

With few exceptions, the productivity of all these natural pastures is very low. Grazed continuously, and at some seasons of the year insufficiently, they have been gradually, but surely, becoming less and less productive. More attention is now being focused on this type of pasture than on any other.

Research Work and Organizations Involved

Federal, provincial, and private organizations are concerned with pasture investigations in eastern Canada. For the most part, committees are formed at the various points composed of workers from different fields who have a definite interest in pasture problems. Other organizations bring together groups of provincial workers or inter-provincial gatherings.

The largest single organization engaged in pasture studies is the Dominion Experimental Farms. The central farm is located in Ottawa and one or more branches or sub-stations are to be found in each province of the Dominion. The more important sub-stations, from the pasture standpoint, in the east are those located at Lennoxville and Ste. Anne de la Pocatière in Quebec, Fredericton, N.B., Kentville and Nappan in N.S., and Charlottetown, P.E.I. The position of these can be seen in Fig. 1 (p. 53). A pasture committee at Ottawa directs and co-ordinates the pasture investigations at all these stations.

Working in close co-operation with Ottawa is the Guelph group at the Ontario Agricultural College, whose position in the western part of Ontario divides the field, and through the agricultural-representative system has a ready channel for distributing information and results.

In Quebec, apart from the federal undertakings, three groups are engaged in pasture investigations. The Provincial Department of Agriculture, through the Division of Rural Economics, is mainly concerned with disseminating information obtained from the more technical institutions; it does a great deal to keep alive a definite interest in pasture work. At Ste. Anne de la Pocatière, seventy miles below Quebec City, L'École Supérieure D'Agriculture fosters a pasture-investigation project.

The third group is that found at Macdonald College in the western end of the province. All the work in the province is generously supported by the Department of Agriculture, and a provincial committee helps to co-ordinate the various undertakings.

Apart from the federal stations in the Maritime Provinces, New Brunswick is the only one of the three, at present, actively engaged in pasture work. As in Quebec, its activities are more along the lines of extension. The following is a list of the more important lines of work now being pursued:

1. Trials with single varieties and strains of herbage-plants to determine productivity, palatability, and the effects of grazing and fertilization.
2. Study of mixtures of various grass and clover strains; results measured by clipping or grazing, or by both methods.
3. Breeding of pasture or dual-purpose pasture-hay strains of grasses and clovers.
4. Methods of improving natural pastures; use of fertilizers, lime, seed, and a variety of cultural treatments.
5. Methods of establishing permanent pastures.
6. Grazing management; rotational versus continuous grazing, single versus mixed stock, light versus heavy and variable rest periods.
7. Co-operative grazing experiments with farmers.
8. Pasture surveys, floral, ecological, and economic; study of floral succession following specific treatments.
9. Annual or supplementary pastures.
10. Nutritional features.
11. Soil aspects; delimitation of the larger soil zones; phosphorus relationships.

Although most of the accumulated data from these projects are at present unavailable, a few results have appeared. The improvement of natural pastures has received more attention than any other single phase. The work of Shutt *et al.* [2] with nitrogenous fertilizers and frequent clipping is well known. Nowosad [4] has discussed the value of mineral fertilizers on natural pastures in parts of Quebec.

Co-operative grazing experiments have been fairly widespread. Table 3 gives a summary of results with dairy cattle, published by the Quebec Department of Agriculture, which corresponds closely with those obtained in the Maritime. Crampton and Raymond [7] report on a three-year grazing trial with steers.

Pasture surveys are being fairly extensively made. Two publications, one by Newton and Nowosad [5], and one by Newton and Stobbe [6], have attempted to relate the existing flora to the soil type in parts of Quebec. Their work shows a wide adaptation of the natural species. A fairly complete list of the existing species is included.

In the nutritional field considerable work is in progress. Papers by Crampton [9] and Crampton and Finlayson [10] record results obtained when rabbits were used to evaluate both pure species and mixed herbage.

Soil zonation is receiving rather belated attention in different sections. Wrenshall and McKibbin [8] discuss some phases of soil phosphorus.

McConkey [3] discusses the use of herbage crops in eastern Canada, pointing out some of the difficulties inherent in the situation. The same author [11] shows some of the possibilities of improvement through the use of the new strains of grasses and clovers.

TABLE 3. *Summary of Results obtained in Grazing Trials with Dairy Cattle. Rural Economics Branch, Quebec Department of Agriculture*

1	2	3	4	5	6	7	8	9	10
1931	283	799	$1.07	$8.50	$2.89	$11.39	$4.39	$7.00	40
1932	659	769	$0.80	$6.17	$1.30	$7.47	$3.56	$3.91	38·5
1933	712	873	$0.93	$8.11	$4.32	$12.43	$4.23	$8.20	37
1934	1,088	788	$0.94	$7.47	$3.95	$11.42	$3.82	$7.60	34

1. Year.
2. Arpents fertilized.
3. Increased milk per arpent in pounds.
4. Average return for milk per 100 pounds.
5. Value of increased milk.
6. Value of reduced feeding expenses and crops saved due to fertilizing.
7. Total increased receipts per arpent.
8. Charged cost of fertilizers.
9. Average gain per arpent.
10. Increased number of cow-days grazing per arpent.

Note: an arpent = 0·8447 acre.

Owing to lack of information, recommendations for the many diverse pasture problems that arise cannot be said to be in any way stabilized. For natural pastures there seems to be much more agreement of opinion and more experimental evidence on which to base advice. Where wild white clover is indigenous the use of a mineral fertilizer, such as a 0–16–6 at a rate of 500 lb. per acre, has been shown to give economical returns, or in some cases a phosphatic fertilizer alone has been used. Where wild white clover is not found then nitrogen is of considerable value, and from 300 to 500 lb. of a 2–12–6 is most frequently used. Figs. 2 and 3 (Plate 6) illustrate the effect of a phosphatic fertilizer where the incoming wild white clover has greatly benefited the sward.

In this account of pasture-improvement work in eastern Canada it has not been possible to present detailed results. Much the greater proportion of the projects have been under way for too short a time to warrant any general deductions. It has been the aim rather to picture the conditions and the detail of the machinery that is being applied to the task. Some of the important aspects of this region may, however, be summarized in conclusion.

The tremendous soil variation that exists points definitely to the necessity of a classification of the particular types on which work is being done. This phase, so fundamental to the investigations, should receive much greater attention.

The climate characteristic of eastern Canada presents a wealth of problems requiring solution. The pasture season, of four or five months, is short and much complicated by the unevenness of the output of herbage. This situation requires intensive studies of management and treatment-factors calculated to spread production over the season as evenly as possible. The question of supplementary crops will doubtless continue to be a necessity in many sections.

There is also the large field, as yet hardly touched, of breeding herbage-plants to meet the rather exacting conditions prescribed by the climate.

The nutrition studies that have been begun promise valuable information as applied to the whole pasture problem.

Really intensive pasture investigations over any considerable area can only be said to have begun about five years ago. With the attention now being focused on this problem, some really fundamental information should be forthcoming concerning the pastures of eastern Canada.

Acknowledgements.—Acknowledgement is gladly expressed for very substantial assistance rendered by many of the pasture workers in bringing together this material for publication.

REFERENCES

1. R. R. McKibbin and L. I. Pugsley, Soils of the Eastern Townships of Quebec. Macd. Coll. Tech. Bull. No. 6, 1930.
2. F. T. Shutt, S. Hamilton, and H. Selwyn, The Protein-content of Grass as influenced by Frequency of Cutting. J. Agric. Sci., 1928, **18**, 411–20; 1930, **20**, 126–34.
3. O. McConkey, Utilization of Hay and Pasturage in Eastern Canada. Rep. Grassland Conference of N. and Centr. Europ. Countries, Switzerland, 1934.
4. F. S. Nowosad, Pasture Studies II. The Effect of some Commercial Fertilizers on the Botanical Composition and Yield of Permanent Pastures. Sci. Agric. 1933, **14**, 57–69. (Separate as Macd. Coll. J., Series 33.)
5. D. E. Newton and F. S. Nowosad, Pasture Studies I. The Relation of Flora to Soil Types in Three Districts of the Eastern Townships of Quebec. Macd. Coll. Tech. Bull. No. 11, 1933.
6. D. E. Newton and P. C. Stobbe, Pasture Studies V. The Relation of Flora to Soil Types in the Counties of Chateauguay, Huntingdon and Argenteuil in Quebec. Macd. Coll. Tech. Bull. No. 14, 1934.
7. E. W. Crampton and L. C. Raymond, Pasture Studies III. Fertilization of Permanent Pastures for Steer Grazing. Macd. Coll. Tech. Bull. No. 13, 1934.
8. C. L. Wrenshall and R. R. McKibbin, A Comparison of some Methods used in extracting Soil Phosphates with a Proposed New Method. J. Amer. Soc. Agron., 1935, **27**, 511–18.
9. E. W. Crampton, Pasture Studies IV. Nutritive Value of Pasture Herbage: Quality of Protein. Emp. J. Expt. Agric., 1934, **2**, 337–48. (Separate as Macd. Coll. J., Series 41.)
10. E. W. Crampton and D. A. Finlayson, Pasture Studies VII. Effect of Fertilization on the Nutritive Value of Pasture Grass. Emp. J. Expt. Agric., 1935, **3**, 331–45.
11. O. McConkey, Pasture Improvement in North-eastern America through the Utilization of Improved Strains of Grasses and Clovers. World's Grain Conference, 1933, Proc. II, pp. 151–9.

Note: Free use has been made of the annual reports of both the Provincial and Federal Ministers of Agriculture, and also of the reports of the Experimental Farms from the Central and Branch Stations. Very useful progress reports, in mimeographed form, have been issued for each of the past few years by the investigators at Ottawa and Guelph.

(*Received August 23, 1935*)

Photo. by Father M. Proulx

FIG. 2. Vegetation of a natural untreated pasture near Ste. Anne de la Pocatière, Quebec. The grass species are largely Agrostis

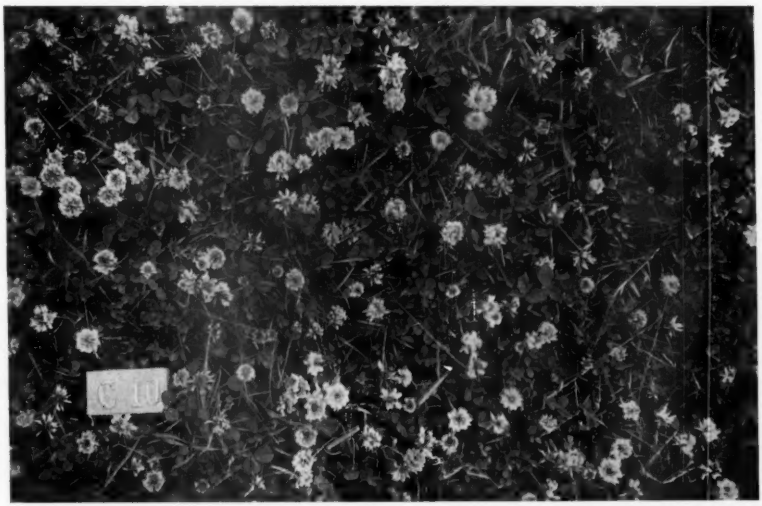


Photo. by Father M. Proulx

FIG. 3. The result of treating natural pasture as in figure 2, with 16 per cent. superphosphate at 500 pounds per acre. The wild white clover now dominates the sward

THE RATE OF LOSS OF EXCHANGEABLE LIME FROM NORTH WELSH AGRICULTURAL SOILS

RICE WILLIAMS

(University College of North Wales, Bangor)

IN North Wales, where the soils are generally developed from non-calcareous parent materials, the practice of liming is essential for the maintenance of fertility. This practice, which was formerly regular and extensive, has during the present century been generally neglected, with the result that the lime-status of many soils has fallen below the level necessary for fertility. Other soils, still containing sufficient reserves from former dressings, must eventually fall to this level in the absence of treatment. Soils of the first type are of frequent occurrence and respond readily to dressings of lime. Experience has shown that the lower limit for satisfactory lime-status in North Wales is in the region of 0·15 to 0·20 per cent. exchangeable CaO. It is, however, undesirable to allow soils to come to this low level before applying lime. The exchangeable lime should probably be about 0·25 per cent., or even higher, not only for the sake of yields, but also to maintain quality. Once a satisfactory lime-status has been reached it should be maintained by regular dressings of lime. The amounts and frequency of these will depend on the net loss of exchangeable lime from the soils under the system of farming practised. This loss consists of the lime removed by crops and drainage, less the additions in the form of manures and the lime converted from non-exchangeable form through natural weathering processes.

The available information on the loss of exchangeable CaO is very scanty. Apart from an important contribution by Crowther and Basu [1] on the Woburn experimental plots very little direct evidence can be obtained. Data from lysimeter experiments, drain-gauges, and crop-analysis indirectly give an indication of the losses likely to occur. Their application is, however, limited to soils of a similar character and under conditions similar to those from which the experimental data have been obtained. Even then, a complete picture of the changes in the lime-status of the surface-layer is not possible, as there is some release of calcium by weathering and from the decay of crop residues; also there may be some movement of calcium from layer to layer in the soil profile. An exact knowledge of the changes in the lime-status of soils can only be obtained from analysis of samples taken at the beginning and the end of a period sufficiently long to give significant differences.

Experimental

With a view to obtaining information of the kind indicated above, exchangeable-CaO determinations were carried out on, (1) samples collected from fields at the College Farm of the University College of North Wales in 1922 and in 1934, and (2) samples collected at intervals from farms in Anglesey. The mean annual rainfall at the College Farm is about 40 in., whilst that in Anglesey is slightly less.

The College Farm samples consist of borings from the surface-soil taken at intervals from an area having a radius of 15 to 20 yards. The position of these areas had been carefully noted at the time of the first sampling. Sampling errors are thus reduced to a minimum. The sampling errors of the Anglesey soils are likely to be greater, as they are representative of whole fields of varying sizes. As these samples were taken at intervals of 8 and 16 years, they will be considered separately from those of the College Farm.

College Farm soils.—Twenty-five samples were taken from six fields in different parts of the farm, representing both arable and pasture soils of varying lime-status and texture. In the short description given below, the letters refer to the field and the figures to the individual samples, of which not more than six were taken from any one field.

The College Farm is partly sloping and partly flat. The flat area includes all of fields I and L and the samples B 3 and D 2, 3, and 4. The remaining samples were taken from sloping ground. Soils B, J, M, and D 1, 5, and 6 are derived from Paleozoic shales and grits. They are stony, medium loams, and, as a rule, gravelly. Drainage conditions are good; although one or two samples, such as B 2 and B 3, show some signs of slight impedance these are comparatively insignificant.

Soil I forms part of the margin of a coarse alluvial fan and is a stony, shaly, medium loam with free drainage.

Soils D 3 and 4 and L 1, 3, and 4 are from a soil type characterized by a wash of local shaly material over boulder clay of Triassic origin. Although these soils overlie a stiff red clay, drainage conditions are as a rule fairly good. In texture they are medium to heavy loams. They contain far fewer stones and more exchangeable CaO than the other samples taken in this area.

Soil D 2 lies intermediate between D 3 and 4 and D 1, 5, and 6, but with definitely impeded drainage.

Soil L 5 is a medium to heavy loam derived mainly from local shales, and shows a somewhat impeded drainage.

Fields B, L, and M are old pastures and have received no manurial dressings during the period under investigation. The flat portion of field D (2, 3, and 4) has been under grass since 1921, and has received dressings of basic slag or mineral phosphates, representing an addition of about 0·012 per cent. of CaO. The remainder of the area, viz. fields D (1, 5, and 6), I and J, has been cultivated under rotation, and has received dressings of farmyard manure and other fertilizers during the period 1922–34.

The analytical results, given in Table 1, include figures for twenty-five soils from the College Farm, and show that, in all except three, the exchangeable calcium has fallen over the period under investigation, and that only in one soil, viz. D 2, has it appreciably increased. In view of this result fresh samples of the soil (D 2) were taken and analysed. The results agreed with those of the previous sample within 0·005 per cent. CaO. Thus the difference could not be accounted for by sampling errors. The explanation for this increase in exchangeable CaO is probably connected with the surface-relief of this field. It slopes down to a flat bottom which, at the foot of the slope, shows im-

TABLE 1. *Exchangeable Lime in, and pH values of, Soil Samples at the College Farm, Bangor*

Soil Number	Exchangeable CaO (per cent.) 1922	Exchangeable CaO (per cent.) 1934	Loss of exchangeable CaO (per cent.)	pH air-dry soil 1922	pH air-dry soil 1934
1A. *Old pasture soils*					
B 1	0·255	0·195	0·060	5·35	5·15
2	0·205	0·150	0·055	5·30	5·00
3	0·190	0·160	0·030	5·45	5·10
4	0·215	0·175	0·040	5·40	5·20
5	0·225	0·155	0·070	5·50	4·90
6	0·255	0·190	0·065	5·45	4·90
L 1	0·305	0·200	0·105	5·80	5·20
3	0·300	0·250	0·050	5·90	5·20
5	0·410	0·295	0·105	5·90	5·45
M 1	0·290	0·190	0·100	5·75	5·50
2	0·180	0·180	0·000	5·30	5·20
3	0·180	0·140	0·040	5·30	5·35
4	0·200	0·155	0·045	5·65	5·35
1B. *Arable soils*					
D 1	0·240	0·210	0·030	5·45	5·15
5	0·195	0·200	0·005*	5·50	5·30
6	0·230	0·205	0·025	5·50	5·25
I 1	0·225	0·175	0·050	5·70	5·05
2	0·235	0·155	0·080	5·70	5·00
3	0·175	0·140	0·035	5·15	4·90
J 1	0·355	0·275	0·080	6·10	5·50
2	0·390	0·315	0·075	6·15	5·75
3	0·395	0·305	0·090	6·10	5·65
1C. *Recent pasture*					
D 2	0·295	0·335	0·040*	5·80	5·90
3	0·460	0·360	0·100	5·85	5·60
4	0·380	0·315	0·065	5·90	5·90

Average fall in exchangeable CaO over a period of 12 years (per cent.) . . . . . All soils . . 0·054; Arable soils . . 0·052; Old pasture . 0·058

Average fall in pH over 12 years . . . . . 0·35

Figures marked * in column 4 are gains.

peded drainage. Further along the flat, where samples D 4 and D 3 are located (100 and 140 yards respectively from the foot of the slope), the drainage conditions are good. If the changes in exchangeable CaO figures are considered in relation to these circumstances, it is found that samples D 1 and D 6 from near the top of the slope show a distinct loss; sample D 5 from near the bottom of the slope shows a slight gain, whilst D 2 from the impeded drainage area shows a definite gain. Farther along the flat, where the drainage is again good, D 3 and D 4 show very distinct

losses. These results suggest some lateral movement of calcium from the upper to the lower levels, with an accumulation in the part of the field with impeded drainage.

If all the figures in Table 1 are averaged, it is found that the loss of exchangeable CaO for the 12-year period is 0·0538 per cent., or 0·0045 per cent. per annum. The loss from the old pastures is, perhaps contrary to expectation, slightly higher than that of the arable soils, being 0·058 per cent. CaO as against 0·052 per cent. Removal by crops and the effect of cultivation in facilitating drainage might be expected to result in increasing the loss of lime from the arable soils. That this does not follow is probably due to the additions, already referred to, of various mineral fertilizers and of farmyard manure. Those applied to the arable soils during the 12 years under consideration were as follows: 1 cwt. of sulphate of ammonia, 4–9 cwt. of superphosphate or basic slag, 5 cwt. of kainit or its equivalent of other potash salts, and 12–24 tons of farmyard manure per acre.

The exact effect of these fertilizers and manures on lime-status is difficult to assess. Crowther and Basu [1], in their investigations on the exchangeable bases of the Woburn plots, found that the losses of exchangeable calcium fell into the following descending order, according to manurial treatment: sulphate of ammonia: no manure: minerals (phosphates and potash): farmyard manure. Thus farmyard manure and minerals conserve the lime-status, whilst sulphate of ammonia increases the loss as compared with the no-manure plot. Unfortunately, they were unable to assess the separate effects of potash and phosphatic fertilizers; but they believe that 'for practical purposes it should be sufficient to regard superphosphate as without appreciable effect on soil reaction or lime-status'. This, however, may not be said of basic slag, for the writer [3] has shown that it conserves the lime-status by increasing the exchangeable calcium. Similarly, the position of farmyard manure in the above series may be attributed mainly to the calcium it contains, for analysis carried out by the writer on a dried sample of manure from the College Farm suggests that about 1 cwt. of exchangeable CaO is returned to the soil in every 12 tons of manure applied.

In view of these considerations, and of the fact that the dressings of sulphate of ammonia were small, it seems reasonable to conclude that the net effect of the above-mentioned added manures and fertilizers will be to conserve the lime-status. This is supported by the figures for the average loss from the arable and the old pasture soils. The arable soils have maintained their lime-status compared with the old pasture soils, despite the probably greater loss through drainage and removal in crops. As the difference is small, it may, for practical purposes, be assumed that the lime-status of the unmanured permanent pastures is reduced at about the same rate as that of cultivated soils receiving normal manurial dressings but no calcium carbonate or lime. Permanent pastures treated occasionally with basic slag would probably maintain their level better than cultivated soils. This suggestion is supported by the figures for some Anglesey soils discussed in the following section.

Anglesey soils.—A number of representative soils from Anglesey farms

were available for the purpose of this work. The information to be derived from the data for these soils was not expected to be as reliable as that from the College Farm soils for the following reasons: (1) The samples consisted of borings taken from whole fields varying in size from 4 to 16 acres; (2) it was not always possible to obtain information regarding manurial treatment; and (3) the soils varied in texture, cultural treatment, and drainage conditions. In general they are of a more open texture than the College Farm soils. It will be noted (see Table 2) that some of the soils have received heavy dressings of basic slag. The effect of the added calcium (1 ton of slag = 0·04 per cent. CaO) has been calculated by assuming that the slag contains 40 per cent. CaO and that an acre of soil weighs 1,000 tons. The values thus obtained have been added to the original exchangeable CaO (column 4).

TABLE 2. *Anglesey Soils*

Soil	*Interval (years)*	*Manurial dressing*	*Exchangeable CaO (per cent.)*		
			Original + added CaO	*After interval*	*Loss*
A 25	16	16 cwt. basic slag	0·280	0·255	0·025
A 30	16	No slag or lime	0·465	0·305	0·160
A 31	16	No information	0·150	0·145	0·005
A 44	16	„ „	0·540	0·395	0·145
A 72	8	„ „	0·280	0·215	0·065
A 74	8	1 ton basic slag	0·360	0·310	0·050
A 75	8	5 cwt. „ „	0·190	0·160	0·030
A 78	8	5 cwt. „ „	0·230	0·200	0·030

Average fall in exchangeable CaO per annum = 0·0053 per cent.

The figures in the above table show that the lime-status diminished over the period, and, as might be expected, the losses of CaO varied considerably. The two soils (A 25 and A 74) which received heavy dressings of basic slag are of interest, since without the allowance for the lime in the slag, A 25 would show an increase of 0·005 per cent. exchangeable CaO over the period of 12 years and A 74 a slight decrease of 0·008 per cent. over the period of 8 years. Thus the basic slag in these soils has maintained their lime-status at a fairly constant level.

The average annual loss of exchangeable CaO is similar to that for the College Farm soils, being slightly higher, 0·0053 per cent. compared with 0·0045 per cent. Thus the losses are of the same order for the two districts. As none of the soils examined contains free calcium carbonate, the foregoing evidence suggests that for non-calcareous soils under lowland conditions in North Wales the average reduction in exchangeable-CaO status is about 0·005 per cent. annually.

Factors affecting the Loss of Exchangeable Calcium

In the preceding section the average annual loss was shown to be about 0·005 per cent. This loss will be governed by three main factors: (*a*) the amount of exchangeable calcium present; (*b*) freedom of drainage; and (*c*) cropping.

(*a*) *Amount of exchangeable calcium present.*—That the amount of exchangeable CaO present influences the loss can be readily demonstrated and is shown graphically in Fig. 1, where the loss is plotted against the amount present at the beginning of the period. All the soils are included in this figure, the loss from the Anglesey soils being calculated on a 12-year basis.

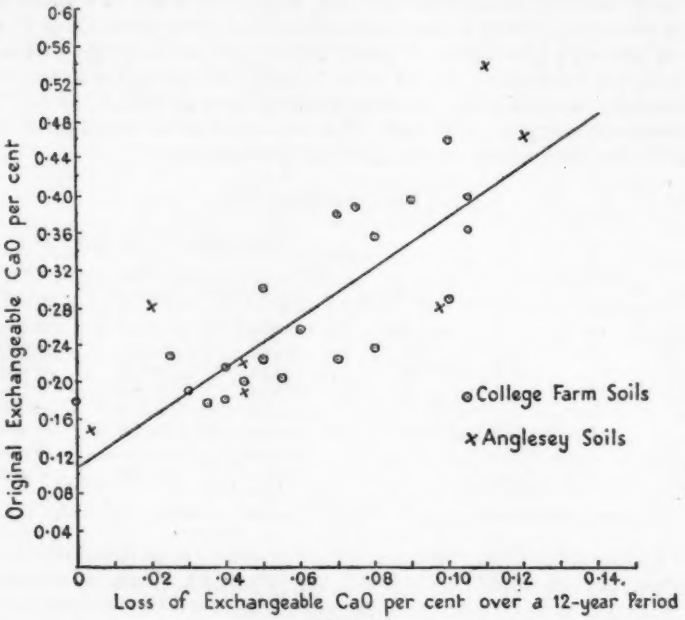


FIG. 1.

It is evident from the above diagram that there is a general tendency for the loss of lime to increase with the amount of exchangeable lime present. If the College Farm soils are divided into two groups depending upon whether their original exchangeable CaO was above or below the figure 0·25 per cent., it is found that the average loss of the higher lime-status group is about twice that of the lower lime-status group, being 0·084 per cent. as against 0·04 per cent. for the 12-year period.

It will be noticed that no soils of exchangeable CaO below 0·12 per cent. are included in this work. They are not common amongst ordinary cultivated lowland soils of normal organic content unless these soils are sandy. It may be that a state of equilibrium is approached somewhere about this figure, where the losses are balanced by the release of calcium through weathering processes. The general trend of the spot-diagram seems to suggest some such point for zero loss lying above zero exchangeable CaO.

(*b*) *Loss through drainage.*—The loss of exchangeable calcium from soils occurs principally through the drainage. For the College Farm

soils some information regarding this loss has been obtained from certain lysimeter experiments. Two lysimeters, 4 ft. square by 4 ft. deep, consist of water-tight tanks into which soil was placed in such a manner as to obtain, as nearly as possible, the natural soil profile. They were filled in 1925. From May 1929—when the soils had been given sufficient time to settle down—to May 1934, it has been possible to obtain figures for the amounts and concentration of the calcium passing through in the drainage. The soils were taken from one of the College Farm fields and originally contained 0·26–0·27 per cent. of exchangeable CaO in the top 12-inch layer. They have been cropped annually and during the above period each has received one dressing of farmyard manure and basic slag at the rate of 12 tons and 6 cwt. per acre respectively.

The total loss of CaO through drainage during the five-year period was:

Lysimeter A	414 lb. per acre
Lysimeter B	386 lb. per acre

This corresponds with an average loss of 80 lb. CaO per acre per annum, and an average content of 23·9 parts CaO per million in the drainage-water. The figures usually quoted in text-books from lysimeter and drainage experiments are much higher than the above, showing losses of from 140 to 330 lb. of CaO per acre per annum, with concentration of over 100 parts of CaO per million. Comparable figures are, however, obtained from the Aberdeen [2] experiments on the Craibstone soil, which is low in exchangeable CaO. The results are very similar, being 19·31 parts CaO per million and a loss of 76·1 lb. CaO per acre from the 'no-manure' plot over a period of 8 years.

(*c*) *Loss by cropping.*—It is somewhat difficult with the data available to assess the net loss from this source. As most of the crops are consumed on the farm a considerable amount of CaO will be returned to the soil in the farmyard manure. The CaO that is lost will be mainly in the form of milk and live stock sold from the farm. The amount lost in this way will be much less than that lost through drainage.

Discussion with Special Reference to Practical Applications

The figures presented give a reasonable indication of the changes likely to occur in lime-status of soils over a period of years under North Welsh conditions. Having regard to the relatively humid climate of this district, the losses are not as great as might have been anticipated. An increased loss would, however, be expected in those districts of North Wales where the annual rainfall is greater than that in the College Farm and the Anglesey areas.

Assuming that the top layer of the soil has an average weight of 1,000 tons per acre, the main results may be summarized as follows:

Average annual loss of exchangeable CaO per acre from all soils . .	106 lb.
Highest annual loss of exchangeable CaO per acre from any soil . .	224 lb.
Average annual loss of exchangeable CaO per acre from College Farm soils of original exchangeable CaO below 0·25 per cent.	75 lb.
Average annual loss of exchangeable CaO per acre from College Farm soils of original exchangeable CaO above 0·25 per cent.	157 lb.

In the earlier part of this paper it has been suggested that the lime-status of North Welsh soils should be maintained at not less than 0·25 per cent. exchangeable CaO. This generalization applies mainly to soils of medium texture. Soils rich in organic matter and heavy soils would probably need to be maintained at some higher level of exchangeable CaO, whilst sandy soils should be satisfactory at a slightly lower level.

From the data summarized above, it would seem that once a satisfactory level of lime-status has been reached, it can be maintained, under North Welsh conditions, by annual dressings of from 1½ to 2 cwt. of lime per acre. This result would of necessity be governed by the efficiency of the dressing in increasing the exchangeable CaO content. It is probable that, following a fairly heavy application, there will be a temporary increase in the rate of loss through leaching. Further, when lime is applied some of it becomes partially inactive through carbonation and caking, and only reacts with the soil very slowly. A 100 per cent. efficiency of the lime-dressing cannot, therefore, be assumed. The writer would recommend dressings at the rate of the highest annual loss, viz. 2 cwt. of lime per acre, in order to maintain the lime-status at the desired level in the soils of this area. In practice this addition of lime would be best accomplished by means of a heavy dressing once during the rotation. The average rotation-period under North Welsh conditions covers 7 or 8 years. Thus an application of about 15 cwt. of lime, or about 30 cwt. of ground limestone, per acre at some convenient time during the rotation would be required. Where the lime-status is below the minimum satisfactory level, a heavier initial dressing than this would, of course, be necessary. In regions of higher rainfall heavier dressings would be needed to maintain lime-status.

Summary

1. The percentage of exchangeable CaO has been determined on samples of surface-soil collected from North Welsh farms after intervals of 8, 12, or 16 years. These samples consist of two types, (*a*) borings from small areas having a radius of 15 to 20 yards, and (*b*) representative samples covering whole fields.

2. The results show an average annual loss of 0·00473 per cent. exchangeable CaO. The loss tends to decrease with the amount of exchangeable CaO originally present.

3. It is suggested that the exchangeable-CaO content of North Welsh soils, if already at a satisfactory level of lime-status, may be maintained by applications of lime or ground limestone once during the rotation at a rate equivalent to an annual dressing of 2 cwt. CaO per acre.

REFERENCES

1. E. M. Crowther and J. K. Basu. J. Agric. Sci., 1931, **21**, 689.
2. J. Hendrick and H. D. Welsh. Proc. First Int. Cong. Soil Sci., 1927, **2**, 358–66.
3. Rice Williams. J. Agric. Sci., 1926, **2**, 196–205.

(*Received July 23, 1935*)

Empire journal of experimental agriculture
v 4, 1936

AN EXPERIMENT ON OBSERVER'S BIAS IN THE SELECTION OF SHOOT-HEIGHTS

W. G. COCHRAN AND D. J. WATSON
(*Rothamsted Experimental Station*)

Introduction

SAMPLING is now of common use in the study of agricultural problems. A recent paper by Yates [1] contains some discussion of the principles which must be followed if a truly representative sample is to be obtained, the most important of these being, to quote the author's own words, that 'the selection of the samples must be determined by some process uninfluenced by the qualities of the objects sampled and free from any element of choice on the part of the observer'. As an example of the biases which may arise in the sampling of agricultural material in cases where the observer's choice has influenced the selection of the sample, Yates quotes a case from the observations of the Crop-Weather scheme of the Ministry of Agriculture. Under this scheme, records are taken by sampling of the growth of the wheat-plant at ten stations. The sampling-unit consists of a quarter-metre of each of four consecutive rows and is marked off for observation by inserting a U-shaped rod, whose arms are parallel and a quarter of a metre apart, close to the ground and at right angles to the rows.

Measurements of shoot-height are made only on the two shoots nearest to each end of each row of a sampling-unit, so that there are eight measurements per sampling-unit. At one of the centres, only three rows were available for sampling, and in order to make up the full eight measurements the observer selected the two additional shoots 'at random' by eye. Comparison of the two additional observations with the six regular ones showed relatively large biases in the former. Of these Yates writes, 'On May 31, when the wheat was under 2 ft. high, there is apparently a simple tendency to select the taller shoots, with perhaps a special preference for the very tall shoots. On June 14, this tendency, though much less, is still noticeable, but there is now a tendency to avoid very high values. On June 28, when the wheat was about 4 ft. high, there is a marked avoidance of the tallest shoots, and also to a less extent of the shortest shoots. The general bias is now strongly negative.' And later, 'The biases are of course of the type that might be expected. When the shoots are low and there is nothing much to be seen except the top leaves, there will be a tendency to pick the higher shoots, but when they have come into ear the observer can see the shoots of all heights, and is more likely to select shoots somewhere near the average, omitting both very high and very low values. The strong negative biases of the last set of measurements show that this selection was not particularly effective in improving the accuracy of the sample.'

At a conference of the observers of the Crop-Weather Scheme, held at Rothamsted in June 1935, the opportunity was taken of carrying out an experiment to see to what extent these biases are common to all

observers who are making deliberate selection. The object of this note is to describe the experiment and its results.

For the experiment, six sampling-units were marked out, and the height of every shoot in each was measured. The observers were told to measure the height of two shoots in each row as usual, but instead of picking the end shoots, they were to select any two in the row which they pleased, so as to give what they considered to be a random sample of the shoot-heights in the sampling-units. There were twelve observers, who were divided into two groups of six. The members of the same group took their observations at the same time, but the order in which they made their selections from the various sampling-units was fixed by means of a 6×6 Latin-square arrangement, so that no two observers were measuring the same sampling-unit together. There were about 20 shoots per row within a sampling-unit, and the experiment was made about a week before ear-emergence, the wheat being 70 cm. high.

The Biases in Mean Height

The means of the 48 measurements on shoot-height for all the observers are shown in Table 1 below:

TABLE 1. *Observers' Estimates of Mean Shoot-height*

Group I		*Group II*	
Observer	*Height*	*Observer*	*Height*
	cm.		cm.
R. W. K.	76·79	R. M. H.	77·87
G. A. T.	76·31	A. J. G. B.	76·14
W. R.	76·87	F. H.	77·19
M. E. B. N.	77·62	A. J. M.	76·08
A. F. H.	73·42	B. J. T.	77·77
H. M.	71·96	I. Z.	72·77

True mean height = 70·75 cm.

In every case the estimate was higher than the true value and in all but three cases the bias was considerable, amounting to about 8 per cent.

The difference of each shoot-height selected by an observer from the mean height of the row in which the shoot lay was calculated. The mean differences per sampling-unit for the members of the first group are shown in Table 2:

TABLE 2. *Mean Differences in Shoot-heights*: Group I

	Sampling-unit						
Observer	*1*	*2*	*3*	*4*	*5*	*6*	*Total*
R. W. K.	$+5{\cdot}88^{6}$	$+7{\cdot}18^{5}$	$+6{\cdot}68^{1}$	$+4{\cdot}48^{2}$	$+5{\cdot}10^{4}$	$+6{\cdot}95^{3}$	+36·27
G. A. T.	$+8{\cdot}88^{2}$	$+4{\cdot}18^{1}$	$+4{\cdot}55^{4}$	$+3{\cdot}72^{3}$	$+3{\cdot}48^{5}$	$+8{\cdot}58^{6}$	+33·39
W. R.	$+9{\cdot}62^{3}$	$+10{\cdot}18^{4}$	$+4{\cdot}05^{5}$	$+2{\cdot}98^{6}$	$+4{\cdot}10^{1}$	$+5{\cdot}82^{2}$	+36·75
M. E. B. N.	$+10{\cdot}50^{4}$	$+7{\cdot}55^{6}$	$+5{\cdot}82^{2}$	$+6{\cdot}60^{1}$	$+5{\cdot}98^{3}$	$+4{\cdot}95^{5}$	+41·40
A. F. H.	$+3{\cdot}12^{5}$	$+3{\cdot}68^{3}$	$-0{\cdot}70^{6}$	$+3{\cdot}72^{4}$	$+2{\cdot}36^{3}$	$+3{\cdot}82^{1}$	+16·00
H. M.	$+3{\cdot}50^{1}$	$+1{\cdot}92^{2}$	$-2{\cdot}70^{3}$	$-3{\cdot}28^{5}$	$+3{\cdot}98^{6}$	$+3{\cdot}82^{4}$	+7·24
Mean	+6·92	+5·78	+2·95	+3·04	+4·17	+5·66	

The small figures indicate the order of the observations.

Time Means

Time:	1	2	3	4	5	6
Mean:	+4·81	+4·88	+4·54	+6·31	+3·25	+4·71

There appear to be fairly large differences in the biases from observer to observer and from sampling-unit to sampling-unit. This is brought out by the analysis of variance on mean differences, which is shown below for the members of Group I. The analysis for Group II is in all respects similar.

Analysis of variance: mean differences per sampling-unit

	Degrees of freedom	*Sum of squares*	*Mean square*
Observers	5	154·4	30·87
Times	5	28·54	5·71
Sampling-units:			
Regression on mean shoot-height	1	59·91	59·91
Deviations from regression .	4	18·66	4·66
Remainder	20	66·61	3·22
Error			
Random sampling variation .	288	1,684·44	5·85

It will be noticed that the 20 degrees of freedom which remain after removing the sums of squares due to observers, times, sampling-units, and the mean have been called 'remainder' and not 'error'. The reason for this is that although these 20 degrees of freedom contain a component representing the sampling variation of the observers, which is the true error, they are also influenced by interactions between observers and sampling-units and between observers and times, if these exist. Thus if the difference in bias between observers were much greater in some sampling-units than in others, this would inflate the 'remainder'. In the absence of anything better, the 'remainder' would have been used as error, but as it happens, we can get a proper estimate of the sampling variation of observers from the differences of the two samples taken per row. This is shown in the last line of the table and has 288 degrees of freedom. It will be seen that the 'remainder' mean square is actually lower than the error mean square, so that the interactions mentioned above appear to be negligible.

Comparing the mean squares of the various items with the error mean square, we see that the differences in the sizes of the biases of different observers are significant. This is quite to be expected from previous experience. The size of the bias was not, however, affected by the order in which the sampling-units were measured, for time-effects are not significant, nor is there any sign in the times-means given in Table 2 of a regular change in the bias from the first sampling-unit measured to the last.

The size of the bias varies significantly from sampling-unit to sampling-unit, and the question arises, to what is this due? In the example by

Yates quoted above, it was shown that the bias in selection was correlated with the true mean shoot-height, being positive when the shoots were low and negative when they were high. A comparison of the mean biases per sampling-unit with the true mean shoot-heights (shown in Table 3) indicates that a similar relation is present here also.

TABLE 3. *Mean Biases and Mean Shoot-heights*

Sampling-unit	*Mean bias*		*True mean Shoot-height*
	Group I	*Group II*	
1	6·92	8·12	59·0
2	5·78	7·63	66·2
3	2·95	2·59	76·4
4	3·04	5·14	74·5
5	4·17	4·45	76·0
6	5·16	5·20	72·3

In the analysis of variance, the linear regression of the mean differences on the true mean shoot-height was taken out. The regression is highly significant, and the mean square of the deviations from the regression line is slightly below the error mean square. The variation between sampling-units, apart from that due to error, may thus be accounted for by the linear regression of the bias on mean shoot-height. The positive bias in the height of a shoot increases by about 0·2 cm. for each cm. decrease in the true shoot-height. This provides a striking illustration of the errors to which human judgement may be subject.

The Distribution of the Sampled Shoots

The distributions of the differences of the heights of the sampled shoots and of all shoots from the means of the rows in which they lay are shown on the same scale by the unshaded and shaded portions respectively of the histogram in Fig. 1. The positive bias already referred to in the sampled observations is clearly shown. A striking feature of the comparison is the much smaller variability in the differences of the sampled shoots, the sampled shoot-heights being much more closely grouped about the mean. Shoots which were smaller than the mean by more than 20 cm. are scarcely represented at all in the samples. This confirms the result found in previous investigations that observers, when given freedom of choice, select samples which conform much too closely to the average, even when they are instructed to make their samples representative of all the material which is being sampled.

The distributions of the differences of the sampled shoot-heights were calculated separately for the centre and outside rows, to see whether the easier accessibility of the two outside rows made any difference to the type of sample which was taken. The results are shown below in Table 4, the two distributions together forming that represented in the unshaded histogram in Fig. 1.

There is no marked difference between the two distributions. That from the outside rows shows, however, a slightly greater variability, hav-

ing rather more observations in the two extreme groups at either end of the scale. The fraction of observations in these four groups was not, however, significantly higher for the outside rows.

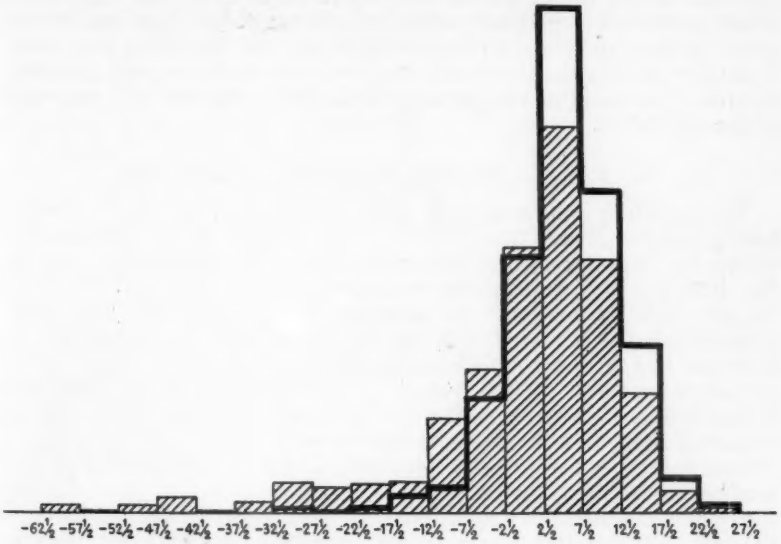


FIG. 1. Distribution of sampled shoots (unshaded) and of all shoots (shaded).

It has already been pointed out that the observers' samples showed a much smaller amount of variation than the population from which they were sampling. A more detailed examination was made of the variation in the observers' samples. For each observer there are eight differences per sampling-unit and an estimate of the variation between these may be made by taking the sum of the squares of the deviations

TABLE 4. *Distribution of the Observers' Differences in Centre and Outside Rows*

Group	−32½−27½	−27½−22½	−22½−17½	−17½−12½	−12½−7½	−7½−2½
Number of observations:						
Centre	0	0	3	5	3	35
Outside	2	0	0	2	7	20

Group	−2½+2½	+2½+7½	+7½+12½	+12½+17½	+17½+22½	+22½+27½	*Total*
Number of observations:							
Centre	43	110	60	35	5	0	288
Outside	58	89	67	31	9	3	288

of these differences from the mean differences and dividing by seven. An analysis of variance was performed on these estimates of variance in the same way as that already described on mean differences. In both groups of observers the differences in variability between different observers were significant. The variability did not, however, differ

significantly, or indeed at all abnormally, from sampling-unit to sampling-unit or from time to time. The observers' estimates of the variability within a sampling-unit lay between 16·0 and 93·4. The correct value from the whole set of shoots was 187·6. Thus even the best of the observers in this respect estimated the variance at less than half its true value, whereas the worst obtained only about a twelfth of the true value. It is worth noting that the three observers who made the best estimates of mean shoot-height were amongst those who made the best estimates of the variability.

The Validity of the Sampling Process actually Used

The sampling process actually used consists, as mentioned above, in taking the two shoots nearest to the ends of the rows. The location within the sampling-unit of the shoots which are measured is certainly free from any element of choice on the part of the observer. The eight shoots which are measured do, however, always occupy the same positions within the sampling-unit, and it is of interest to see whether in this case they formed a representative sample of the shoot-heights in the six sampling-units. One reason on general grounds for doubting this is that with a patchy growth the outside shoots of a plant have a greater chance of being selected than the inner shoots, owing to the presence of a blank space in the row next to the plant. In the present case the growth was fairly even.

We may examine the heights of the 48 end shoots in the same way as the observers' samples were examined, and consider whether the former give an unbiased estimate of the true mean shoot-height and a reasonably good representation of the distribution of shoot-heights.

The mean of the 48 end shoot-heights was 71·375 cm., the true mean being 70·75 cm. The difference is +0·625 cm., its standard error, calculated from the 48 deviations, being ±1·987 cm. The difference is well within its standard error, so that there is no sign of bias in the estimate of mean shoot-height.

The distributions of the differences of the end shoots and of all shoots from the row means are shown by the unshaded and shaded histograms in Fig. 2. The unshaded histogram shows no sign of abnormality and could reasonably be regarded as a random sample from the whole distribution. In particular, the estimate from the end shoots of the variance with a sampling-unit, calculated in the same way as for the observers' samples, comes to 174·4, which agrees well with the true value of 187·6.

The evidence of this experiment thus provides no reason to doubt the validity of the sampling process which is being used for shoot-heights in the Wheat Sampling Observations.

Conclusions

It is obvious that samples that are picked by a process of randomization which gives every sample in the population an equal chance of being picked, must be representative of the population from which they

are drawn and give an unbiased estimate of the quantity which it is desired to measure. Those who have little experience of the technique of sampling might, however, be unwilling to admit that they could not do as well, or better, by choosing the samples themselves. In this experiment, out of twelve observers, all of whom have had some train-

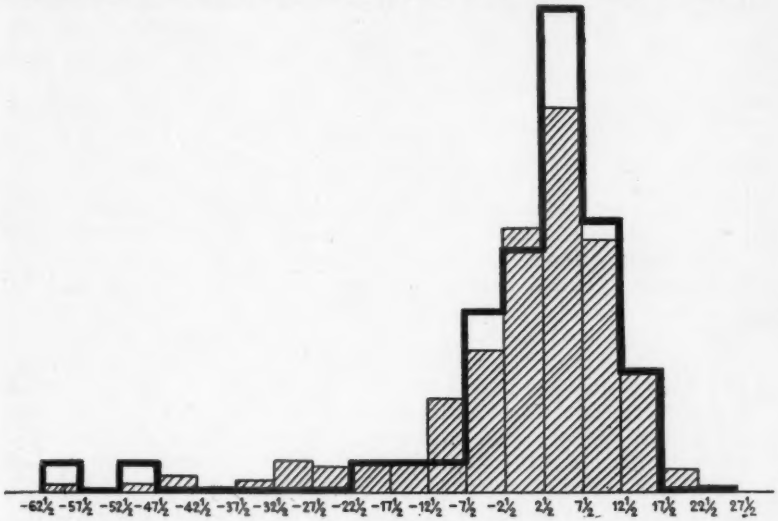


FIG. 2. Distribution of end shoots (unshaded) and of all shoots (shaded).

ing in sampling, not one managed to pick a sample that could be called representative of the material from which they were sampling, and all except three obtained relatively large biases in their estimate of the quantity, mean shoot-height, which was being measured. Further, the biases, both in mean shoot-height and sampling variance, showed large differences from observer to observer. What is even more serious and striking is that the individual observers were not consistent throughout the experiment; the positive bias in selection increased regularly as the mean height of the sampling-unit decreased.

This experiment, in short, very strongly supports the evidence from other investigations that the only sure method of avoiding bias is for the sampling to be random. The plea has sometimes been made that observer's bias is not important provided that the same observer does all the sampling. The answer to that in the present case is that there is no excuse for bias at all in such a simple problem as the estimation of the shoot-height of a field. In many sampling problems, however, particularly in sampling from bulk, it is much more difficult or troublesome to obtain a proper random sample, and for this reason the plea merits some investigation.

In the first place the plea is based on the assumption that the observer's bias remains constant. Neither the present example nor the one discussed

by Yates supports this view; in both, the positive bias in the estimate of mean shoot-height decreased regularly as the true mean height increased. Thus the observer's estimates of differences between the mean shoot-heights of different varieties in the field would be biased. The true mean shoot-heights on this date (June 17) and the observer's estimates are shown below for two of the varieties grown at Rothamsted:

Variety	*True values* cm.	*Observer's estimates* cm.
Victor . .	70·7	75·8
Yeoman . .	63·7	70·5
Difference .	7·0	5·3

Victor was the variety used in the experiment. The observer's estimate for Yeoman was calculated from the regression of observers' bias on true mean shoot-height obtained above. The true difference in height, 7·0 cm., would have been under-estimated by 24 per cent. A similar case occurs in the example discussed by Yates [1], in which the growth-rate would have been under-estimated by 9 per cent.

Even granting that an observer might have a constant bias, the uses to which his results can be put are very limited. A constant bias would give a correct estimate of differences, but almost all other estimates based on his figures, such as for example percentage differences or regression coefficients, would be biased in different ways. No one can foresee, when making observations, all the estimates or comparisons which may be made from them at some future date. Further, the comparison of one observer's work with that of another will be vitiated by the fact that they will have different personal biases; and this difficulty is almost certain to arise in any work carried on at more than one place, or for any length of time at the same place. In short, the presence of observers' bias in sampling results greatly detracts from the value of the results, and one of the most important problems in the application of statistical methods to agriculture and industry is to devise reasonably quick methods of taking a proper random sample in cases where the material sampled is difficult to demarcate or handle.

REFERENCE

1. F. YATES. Some Examples of Biased Sampling. Annals of Eugenics, 1935, 6, Pt. II.

(*Received November 5, 1935*)

THE DEVELOPMENT OF NATIVE AGRICULTURE IN THE NUBA MOUNTAINS AREA OF KORDOFAN PROVINCE, ANGLO-EGYPTIAN SUDAN

G. F. MARCH

(*Assistant Director of Agriculture and Forests, Sudan Government*)

THE Nuba Mountains area is approximately 150 miles square and lies between Lat. 10·18° and 12·15° N. and Long. 29·00° and 31·3° E. It consists of several fairly well-defined ranges of rocky hills and numerous isolated outcrops of granite. Extensive and comparatively level valleys surround the hills.

The pursuit of agriculture in this region depends entirely on the rainfall, which, presumably due to the presence of the hills, is, taking the area as a whole, consistent, and usually well distributed throughout the wet season. Practically all the rain falls between early June and the middle of October. Local variations in the total annual rainfall may run from 25 to 40 in., as heavy storms are often local in their incidence, but, generally speaking, one expects to get an annual rainfall of more than 30 in. over most of the area. The soil is very variable, ranging from clay or heavy loam in the valleys to what is almost gravel close to the hills.

The inhabitants can be divided into two main groups, Nubas and Arabs. The former are a negroid race, the latter are mostly rather dark-skinned for Arabs and in this country are known as *Baggara*, which means 'cattle-owning'.

Had it not been for the mountains, the Nubas would probably have been overrun by the Arabs in the old slave-trading days. As it was, they were able to defend themselves in their mountain fastnesses and to retain their racial characteristics. They were able to grow most of their food-requirements on terraces on the hill-sides. There is an adequate water-supply, either on, or close to the foot of, most of the mountains. It will be seen, therefore, that, in times of danger, there was very little necessity for the Nuba to leave his mountain stronghold. His wants from the outside world were few; he wore no clothes, his cooking utensils were made of local pottery, and his houses were made of stone, mud, grass, and branches cut from trees, of which there is a plentiful supply both on the hills and on the plain.

Evidence of fortifications can still be seen on some of the hills. They generally took the form of rough stone walls built across the narrow valleys or gorges which gave access to the mountain mass. In some cases the Nuba did not rely on one line of defence only, but built two or even three walls one behind the other.

This comparative isolation has had its effect on the Nuba; though of a naturally genial nature, he is shy of strangers and of people whom he does not know well. This makes it essential for any one, who wishes to introduce him to new crops or to new (to him) methods of farming, to get to know him and to be known by him. This task is made more difficult by the fact that several different languages are spoken by different

sections of the race and many dialects of these languages are in common use. It is no uncommon thing to find the Nubas living on two hills only 10–20 miles distant from one another speaking different languages.

Another effect that isolation has had on the Nuba is that it has made him independent. From time immemorial he has had to rely on himself for all his wants. These being few, and the chief of them being food, the result is that, judged by African standards, he is a good cultivator and a steady worker. Any one making a journey through the Nuba Mountains in the early part of the year, after all the grass on the hillsides has been burnt, cannot fail to be amazed at the enormous amount of work which must have been needed in the past to complete the vast amount of terracing which is then easily seen.

Up to the present little has been said about the Arab section of the population. It is probably true to say that most of the Arabs found in the Nuba Mountains were originally Baggara. Many of them are, however, not true Baggara to-day. The true Baggara depends for his livelihood almost entirely on his cattle; during the wet season he moves his herds north out of the Nuba Mountains area, and gradually moves south again after the rains, when grass and water become scarce in the north. Many of the Arabs now found in the Nuba Mountains, though originally true Baggara, have lost their herds through one cause or another, and have become sedentary, depending on their crops for their livelihood.

In 1899, when the present Sudan Government came into being, conditions in the Nuba Mountains were very unsettled. The Nuba still kept to himself and was difficult to approach for administrative purposes; communications were bad; Nubas and Arabs were always quarrelling, and even one section of Nubas was always liable to fight another section.

As time went on conditions began to improve. Both Nubas and Arabs were made to realize that there was now a Government whose orders had to be respected.

About twelve years ago the Government had made considerable progress in the administration of this area, but even then considerable sums of money had to be spent almost annually on the employment of troops to aid the administration in enforcing its orders, and in keeping peace between the various sections of the inhabitants.

At this stage the Government decided that the least expensive method of procedure would be to try to increase the interest of the inhabitants in agriculture; in other words, to 'turn their swords into ploughshares'.

In this connexion the introduction of a cash crop appeared to be the solution. It was considered that American-type cotton would grow well under the conditions prevalent in that area, and cotton at that time was fetching very high prices on the world's markets.

The Government at first endeavoured to interest private enterprise in this proposed development of cotton-growing. However, their efforts in this direction failed, and it was finally decided that the Government must initiate cotton-growing itself, and that it must be prepared to carry on the industry for some considerable time.

It fell to the lot of the writer to be sent to the Nuba Mountains in 1924 to start cotton-growing and to organize the new industry from the start.

In eleven years the output of cotton has risen from nothing to over 400,000 kantars of seed-cotton, a kantar being approximately 100 lb. Expressed in bales of American cotton (480 lb. net), this means 25,000 bales, which at 6*d.* per lb. at Port Sudan means a cash crop worth £300,000, of which slightly less than half goes to the grower, the remainder being used up to pay the cost of ginning, transport, &c. Seven ginning factories have been erected by Government in this area, and two more will be completed shortly. Most of the cotton grown is sold under marks N.M.K. or N.M.T., and it usually averages nearly 1*d.* per lb. in value over standard American.

Eleven years ago the chief crops grown in the Nuba Mountains consisted of dura (*Sorghum vulgare*), simsim (*Sesamum indicum*), and ground-nuts (*Arachis hypogaea*). Since then, as already mentioned, cotton has been added. This has been effected partly, but by no means entirely, at the expense of the other crops.

The native system of farming, which has been in force from time immemorial, has hardly been changed at all up to the present. It consists of a partial clearance of the land (the larger trees only have their branches lopped off) and then the growing of crops for three or more years running. After this the cultivator moves on and clears another area, leaving his old plot to recover its fertility under natural conditions. He may or may not move back to it after the lapse of some years, but when he does the operation of clearing is nearly as heavy as it was in the first instance.

The use of ploughs, or indeed of any animal-drawn implement or cart, was unknown until very recently. Even now the Nuba section of the inhabitants has no idea of the use of animals, even for pack-transport purposes. The Arabs, on the other hand, have always used their bulls for riding and for pack-transport.

The Government started two or three demonstration farms seven or eight years ago. On these the use of animal-drawn implements and carts has been shown, and a few cultivators are now copying the example given them.

The tools in general use by cultivators are distinctly crude and consist of several different forms of what we should call a hoe, or, in the case of the cruder forms, a spud. On the heavier land all the hoeing is done by a man squatting down and pushing a short-handled spud in front of him.

Under the present system of native agriculture, land is never under cultivation long enough to become really clear of weeds and grass, consequently the amount of hoeing which is necessary to produce a good crop is always heavy. On the demonstration farms it has been shown that where land is kept under continual cultivation by means of a rotation of crops, the amount of hoeing necessary is very materially reduced after a few years.

It was realized from the first that the introduction of a cash crop like cotton was only the first step in the agricultural development of this area. It was nevertheless a very necessary one, as without money very little can be achieved. Progress has been so rapid that it is now possible,

and even urgently necessary, to introduce the next step. This is the adoption of rotations coupled with the use of animal-drawn implements. At the present time cultivators have become so bitten by the desire to make money by cotton-growing that they are tending to neglect their food crops. It is hoped to introduce a rotation whereby only one-third of the land under cultivation each year is under cotton, the remaining two-thirds being half under grain and half under a leguminous crop or, alternatively, simsim. The question whether a fallow is really necessary to keep up the fertility of the soil has not been definitely decided yet.

The general effects of such agricultural development as has taken place up to the present, beyond the important fact that the local sword is indeed fast being turned into a ploughshare, are as follows:

(*a*) The Government has been able to administer the area much more closely. What were, until recently, scattered semi-independent units of the same, or closely allied, tribe, are now being welded together under a comparatively small number of native administrations. This in itself will materially aid further agricultural development. It will be readily understood that agricultural propaganda is likely to be far more successful if it is passed on to the cultivator through his own native administration, rather than directly by agricultural officers. This is especially true of Nubas, among whom the agricultural officer is always up against the language difficulty referred to above.

(*b*) The Government has been able to provide greater medical and educational facilities, and also to improve communications. I might almost say 'to provide communications', as eleven years ago there were practically none.

(*c*) It has been possible to cut down military garrisons, and consequently to save expenditure.

(*d*) Trade has improved because cultivators have money to spend.

(*e*) The collection of taxes is now comparatively easy.

Up to the present, agricultural development has not affected the local native agricultural systems or methods of cultivation to any very great extent. There is certainly far more land under cultivation than there used to be, and a valuable cash crop has been successfully introduced. Cultivators can also obtain small supplies of improved seed of various crops other than cotton from the demonstration farms. Cotton-seed is issued by the Government free to cultivators, and no other cotton-seed than this may be sown.

After a further eleven years of agricultural development it is hoped that there will be a very different tale to tell. A start has already been made to try to introduce the use of rotations, and of animals for cultivation. Every assistance is being given to chiefs to run small farms on the accepted principles of what we may call mixed farming. It is hoped that after the cultivators have seen the effects of farming in this way for a few years, they will adopt the new (to them) method without much further persuasion.

(*Received July* 29, 1935)

SOME EFFECTS OF THE DEVELOPMENT OF THE COTTON INDUSTRY ON NATIVE AGRICULTURE IN UGANDA

C. G. HANSFORD

(*Mycologist, Department of Agriculture, Uganda*)

THE effects of the cotton industry upon the Uganda native and his agriculture have been so great that it appears best to treat the subject by comparing pre-War with present conditions: the period 1914–18, when the cotton industry was still comparatively small, marks a convenient transition period.

Before the War the primary and practically the sole object of all native cultivation in Uganda was to obtain food for the population. In this matter every village, and, indeed, almost every household was a self-contained unit; transport of agricultural produce from district to district hardly existed, and there were no large centres of population dependent upon outside communities for their food-supplies. Under such conditions land was cultivated merely to ensure an adequate food-supply; the population was distributed in small groups of huts scattered through the general bush and grassland, each group having its small patches of food-crops. As the land around the huts became unprofitable for cultivation, the natives either opened new fields from the bush, or abandoned the site and moved elsewhere. With the limited areas necessary to support each unit of population there was then no lack of 'virgin' land to act as a reserve. The population and the herds of cattle were kept in check to some extent by inter-village and inter-tribal disputes; the cattle were also controlled by epidemics of rinderpest and other diseases.

These conditions, which had probably prevailed for centuries, together with the very limited amount of agriculture, had practically no effect upon the fertility of the land as a whole. In the more thickly populated areas of Buganda and Busoga a very advanced type of agriculture was practised; the primary food-crop was the banana, supplemented by sweet potatoes, ground-nuts, and various beans. It was the duty of the women of each household to cultivate the banana plantations and to ensure a regular and sufficient supply of fruit. The men did comparatively little, except to clear the land for new plantations; for the rest, the man's duties were those of a warrior and protector. A very efficient method of agriculture was evolved; the banana plantations were carefully tended, and the soil was covered with a mulch of weeds, and waste leaves and fibre from the bananas. All early travellers in Uganda were greatly impressed by this high standard of agriculture. With the careful cultivation and mulching practised, the soil deteriorated but little through erosion and exposure to the sun, and the banana plantations could be considered as permanent. Occasional replanting was necessary, owing to the old stools of the bananas gradually becoming raised above the general ground-level.

In the drier parts of the country the main food of the natives was 'bulo' (*Eleusine coracana*). This is an annual crop, taking some five or six months from sowing to harvest, and often two crops per year were

sown, though not on the same patches of land. Ground-nuts and various beans were sown on the old bulo fields to supplement the diet; for the rest, large herds of cattle were kept. Apparently there was a regular rotation of the bulo fields, each of which was cultivated for one or two years, and then allowed to revert to grass and bush for some five or six years. The only permanent clearings were the hut sites and cattle kraals. In spite of the lighter soil of these areas as compared with that of the banana areas of Buganda and Busoga, little erosion of the soil could take place during the short periods of cultivation. The bulo fields were small and surrounded by grassland which acted as a barrier to serious erosion.

In all areas cultivation was entirely by hand, various forms of hoe being used; in some areas the actual tillage amounted to little more than the removal of the natural grasses and a surface-scratching of the soil. As a rule deeper cultivation was employed in Buganda, where an indigenous grass, 'lumbugu' (*Digitaria abyssinica*), is a menace to all agriculture, and unless this is controlled very poor results are obtained.

The history of the development of the cotton industry has been dealt with elsewhere;[1] it suffices to say that at present about a million acres of this crop are cultivated every year in Uganda. A large proportion of this area represents an increase in the cultivated area, and this increase has reacted upon the native and upon his general outlook on life.

Apart from propaganda and general advance in education of the native, the growth of the industry has been assisted by economic and other pressure upon the population. Many cases still occur of natives regarding their cotton crop as the chief means to enable them to pay their taxes in cash; and once the seasonal taxes have been paid, these individuals have little interest in the crop. It has been estimated that some 15 per cent. of the 1934–5 cotton crop in Lango was burnt by the native growers at the end of the season, when the plants were uprooted; having paid their taxes for the year, they did not feel inclined to pick the remainder of their crop merely to increase their cash income. In the future such cases will disappear, as the native is realizing more and more the benefits he can obtain from the possession of money.

Hitherto, in the stages of rapid extension of the industry, all possible attention was concentrated upon getting the natives to grow the crop, and to extend their acreage year by year. We have now reached the stage at which most of the natives are familiar with the crop, and with some of the advantages to be gained from growing it; we are now faced with the more difficult problem of improving the standards of cultivation and thus increasing the yield per acre. To some extent the more intelligent and ambitious natives are working to this end, but in many areas little or nothing is being done. Much propaganda and education will be required to obtain satisfactory results throughout Uganda. In many areas it has proved an almost hopeless task to induce the natives to re-sow blank holes in their cotton plots; and progress in this matter is not assisted by the attitude of some chiefs, whose sole concern is to return as large as possible an acreage under cotton, and who care little about the

[1] See the Annual Reports of the Uganda Dept. of Agriculture; also various papers in the *Empire Cotton-Growing Review*.

condition of plots already sown. The result is that much of the acreage planted has to be discounted as unproductive, and the average yield per acre is lower than it need be. The variety trials conducted by the Agricultural Department at some ten or eleven centres in the Eastern Province usually show a large increase in yield over that of the native cotton around them, in some cases double or treble; this is probably the result of careful filling of blanks and better cultivation. It would be more economical to fill blanks in the early sowings than to expend labour upon later sowings, even if these were slightly reduced in acreage, as in any case the later sowings do not give as high a yield as early sowings. Continuation of the present system of acreage-expansion is likely to prove disadvantageous in the future, in so far as it means less care of the plots planted early in the season. The raising of the average yield per acre is likely to achieve better results in the future than further large extensions of acreage under cotton. In encouraging the native to take better care of his plots, we have either to combat his natural apathy or to utilize it by showing him that, for the same cash return, less labour is required to grow one acre of good cotton than two acres of rather poor cotton.

In the 'banana areas' of Buganda and Busoga most of the cotton is grown separate from the banana fields, and the two cultivations of bananas for food and cotton for cash bear little relation to each other. New land may be opened for cotton and later planted to bananas, but the latter are a permanent crop. Almost all native cultivation in Buganda is still carried out by hand, but in Busoga ploughing has considerably extended of late, and the area under cotton has much increased. It is still too early to assess the advantages or disadvantages of this development, as we have little experience of the effects of ploughing and of more frequent cultivation of land in Busoga, which is quite different from the land in Teso and Bugwere, where large-scale ploughing was developed earlier.

Of late there has been a marked deterioration in the general standard of banana cultivation in Buganda, to which many factors have contributed, one of the most important being the gradual emancipation of the women from their previous condition of virtual slavery on the land with little or no compensating labour on the part of the men. The cotton crop has enabled each family to enjoy a regular source of income in cash, much of which is spent on clothes and bicycles, and consequently the natives are no longer tied down to their own holdings or villages, but can travel to inspect and sample the amenities of the larger towns and trading centres. The banana cultivations have therefore received rather less attention, especially as the women accompany their menfolk on their travels, or even travel without them. Exceptions are found chiefly in the outlying areas, or in plantations belonging to the older generation, who are naturally more conservative. The lower standard of banana cultivation now practised is largely responsible for the recent increase of the banana weevil (*Cosmopolites sordidus*), which has become quite a serious pest in some areas, and further reduces the yield of food per acre.

In Buganda, owing to the development of cotton production, the

cultivated area has extended at the expense of the forests and grasslands on the slopes of the hills. Hence soil-erosion has become a problem, and the natives must now be taught to take all possible precautions to prevent it. In the more densely populated areas the reserves of land are now comparatively small, and conservation of the fertility of the present cultivation is all the more important. With good standards of cultivation the banana food-supply of the population should remain assured indefinitely, but there has been a decided tendency to lower the old standards, and even to replace the banana by sweet potatoes, with consequent increased danger of soil-erosion. Every effort should be made to induce the native to return to his old intensive cultivation of bananas, and thus to control the weevil borer. Such a policy would lead to an improvement in the cultivation of other crops, including cotton.

Many of the Baganda are ambitious to become landowners, so that in the future they may settle on individual holdings and develop an inclination to conserve the fertility of their own land sooner than less settled tribes. At the present time there is room for improvement in the attitude of the large landowners and chiefs to this question. The former, in particular, appear to regard their estates purely as a source of revenue from rents, and few concern themselves with the standard of agriculture practised by their tenants. As these large estates become split up on the death of their owners, there is hope that in the future the owners will be forced to cultivate their holdings themselves, as these will be too small to support them as landlords. In this way the pressure of economic necessity is likely to help in raising the general level of agriculture in these areas.

Unfortunately there are now large areas in Buganda where the production of cattle manure is very limited; but with improved control of cattle diseases and pests the herds may be expected to increase and then mixed farming is likely also to increase. It is improbable that the dangers of over-stocking and over-grazing will occur in Buganda for some years to come.

The 'bulo areas' of Teso, Lango, and Bugwere are areas of comparatively light soil, and have a long dry season from November to March. At other times they are liable to very heavy falls of rain, often more than an inch falling in an hour; between these heavy rainstorms are periods of one to three weeks of hot dry weather. If the soil is bare during the heavy storms, serious erosion may occur even on very gentle slopes; in any case much of the water runs off the surface and is lost for agricultural purposes. The result is that these areas, even under natural conditions of bush land, look very dry as compared with Buganda and Busoga, where the soil is heavier and the rainfall more evenly distributed. The elephant grass (*Pennisetum purpureum*) characteristic of the latter districts does not occur to any great extent in Teso or in most parts of Lango and Bugwere.

In these 'bulo areas' the cotton crop has been included by the natives in rotations with their annual food crops. A common rotation in Teso is for fresh land to be opened in April and May for planting to cotton some five or six weeks later. The cotton is followed by bulo, sown in January

or February, as soon as there is enough moisture in the soil to permit germination; and the bulo crop is followed by a second crop of cotton, sown immediately after the bulo harvest in June–July. After the second cotton crop is finished the land may be sown with ground-nuts, simsim (*Sesamum indicum*), beans, or sweet potatoes; alternatively it may be abandoned. Many plots are cultivated for at most three years, after which the land is allowed to revert to grass and small bush for some five or six years before it is again cultivated. The result is that even in centres of fairly dense population there always appears to be a large reserve of land uncultivated, which is utilized for grazing the large cattle herds. Under primitive conditions the cultivated area of each village was restricted to that necessary for food-production, and, owing to the long periods of rest under grass and bush then possible, the effect of cropping the land was practically negligible; but with every extension of the area cultivated, the periods of rest are shortened. Also, since these areas have been ploughed, individual plots have been enlarged and soil-erosion has correspondingly increased, especially where the furrows left by the plough do not conform to the contours of the land. Cattle numbers have increased side by side with the development of cotton and the better administration of the country; the natural control by inter-village strife and by epidemics of disease has been removed to a large degree. All these factors have resulted in increased demands on the soil for crop-production and for grazing during the intervals between cultivation periods; in some areas the soil is evidently deteriorating.

An additional factor has recently become more pronounced than in the past, namely, the increased tendency of the native to 'clean clear' his cultivated land. Under the old conditions, even if this were practised, very little effect was produced on the country as a whole, on account of the small areas so cleared, but as the cultivated area has extended the effect of this practice upon the general aspect of the country has become more marked; in Kumi county of Teso district the land is now practically denuded of trees and bush. The more intensive grazing now occurring aids this process by retarding the natural regeneration of the bush flora. The area mentioned is now somewhat deficient in water-supply, but it is difficult to determine to what extent this is a direct result of the clearing of the bush.

In the dry season the whole of the grass covering the land is burnt off. This practice appears to have been general for many years, but it is conceivable that under bush conditions the effect was less dangerous than it is in areas now under prairie, where the bare soil is exposed to hot dry winds and sun, and at the beginning of the rainy season is liable to heavy erosion. Kumi county may be an extreme example of the processes at work, but there are other areas in which the early stages are now becoming visible. The native population is tending to migrate from Kumi into areas close by, and if this continues we may expect the prairie area to encroach upon them in the near future. The development of cotton-cultivation must be held responsible for much of this change, though other factors have also assisted. At the moment it appears, therefore, that in the areas of lighter soils there are grave dangers attendant upon

the extension of the cotton and cattle industries. In these areas it has become very important to develop a system of agriculture that will conserve the natural fertility of the soil, or even increase it; and in areas like Kumi to evolve a method of regeneration before the processes at work have gone too far.

At first sight the obvious solution is to settle natives on individually-owned holdings of a more or less permanent nature, and thus give them a direct interest in the improvement of their land. Large herds of cattle are available for use in a system of mixed farming. One of the great obstacles in the way of this solution is that the whole idea of individual ownership of land is foreign to the natives of these districts (Teso, Lango, and Bugwere). It may be possible to adapt the idea of mixed farming to small communities, using each village as a unit, rather than individual households. Under present conditions such adaptation is likely to progress more quickly than settlement of these tribes on individual holdings.

In any case, before progress can be made the native must be convinced beyond doubt that it will pay him well to abandon his present ideas. He must first be shown the superior value of a permanent holding on which mixed farming is pursued, as compared with his present system of shifting cultivation. Attempts in this direction are now being made by the Agricultural Department, and many small holdings have already been established. It is still far too early to say if success has been achieved, and the systems of cultivation and crop-rotation now being used on them may need considerable revision later in the light of further experience or future changes in economic conditions. It is probable that in any case some adaptation of the present system of shifting cultivation, or rotation of cultivation-periods with grazing-periods, will be necessary on these holdings; in fact, those at Serere are already being run on such a system.

These demonstration holdings will have to prove very successful indeed to overcome the natural prejudices of a primitive agricultural people, and until they have done so it is useless to expect the population as a whole to follow the example set them. On the holdings mixed farming is practised, the manure from the cattle kraals being used on the areas set apart for the various crops each year in regular rotation. There is some evidence that in bygone days the Teso did make some use of the manure from their kraals, but they do not do so now. Much propaganda is needed at the moment to impress upon every native the value of this manure, and to demonstrate the profit to be obtained from the labour expended in carting it to the fields. One great drawback is that wheeled transport is not available to the native, but he can with little expense make crude sledges to transport the manure.

Green manuring has been suggested as a possible means of improving present conditions, but apart from the fact that it is likely to prove impossible to induce the native to expend his labour on a crop merely to dig it into the soil again, the results obtained on Serere Plantation in the past indicate that under the special conditions of these districts this form of manuring is of doubtful advantage, as it entails extra cultivation of the soil and consequent loss by erosion.

Although the old method of hand-cultivation has certain advantages

over ploughing, it is obvious to any observer that the latter has come to stay, and is rapidly extending into all districts. By means of it the native is able to bring more land into cultivation with less labour. It therefore remains for us to devise methods of cultivation by plough best suited to local conditions; investigation is required into the best type of plough, the best time to plough the land, the optimum depth of ploughing, &c. It is still possible that a type of plough which leaves the soil in a state more comparable with that produced by hand-hoeing might prove better than the present mould-board type, which inverts the soil and also tends to form a plough sole on some types of soil.

We are still ignorant of the effect of heavy grazing on the local flora and soil, but it should be possible to obtain data on this point from the demonstration holdings mentioned above, provided the cattle on them are kept within the holdings and not allowed to roam, as they are now. At present it is impossible to obtain any accurate data on the area per head of cattle needed for grazing throughout the year, and this lack of information becomes important in the designing of demonstration holdings; the grazing area allotted at present is a mere guess.

Control of the clean clearing of cultivated areas is admittedly necessary, and steps are being taken to stop the natives ringing and burning the larger trees they encounter when opening new fields. Afforestation of the badly denuded areas, such as Kumi, presents difficulties. If trees are planted on a large scale, the question arises as to the best position for the plantings: on the tops of the ridges or in the swamps. An area sufficient for the food and cotton requirements of the natives must be reserved for cultivation, as well as sufficient for grazing their cattle. From the health point of view it would be preferable to plant the swamps, but this leads to dessication through improved drainage, and at present these swamps supply water for the population and the cattle. From the standpoint of soil-conservation and prevention of erosion, it would be better to plant the tops of the ridges, and to limit the cultivation areas to the gentle slopes, where precautions must be taken to prevent erosion by surface-water.

The main problem in the further development of cotton production and of native food production in Uganda is to increase yields rather than to extend the cultivated area. Such increase can be obtained partly by producing improved varieties of cotton and of native food-crops, and partly by introducing improved methods of agriculture, notably mixed farming. The settling either of individuals or of small communities on permanent holdings is likely to lead to progress, but is certain to be very slow and gradual, especially in the Eastern and Northern Provinces. It is possible that in some areas the native now obtains just as good results from his present method of shifting cultivation as he would if settled on a permanent holding. In the future, however, it is probable that the results from the present system will fall off, especially in areas of fairly dense population; for after the area available has all been cultivated once, the periods of rest from cultivation are certain to become progressively shorter. At the moment we need to obtain all possible data on intensive cultivation of small areas of land, on a system of mixed farming and manuring with cattle manure, the grazing of the cattle being also limited

to definite areas. If possible we should set the natives an example by means of demonstration holdings.

Past experience on government plantations has shown that, provided soil-erosion can be controlled—a very difficult matter—it is possible to cultivate the land almost indefinitely by the use of fairly heavy applications of cattle manure. The erosion under cotton is far above that under other native crops, and attempts should be made to control it. Some degree of control can be obtained by interplanting cotton with ground-nuts, with the additional advantage of reducing the cultivation area for the same total production and expenditure of labour. Recent experiments indicate that this interplanting is possible under some conditions, and that the ground-nuts have little effect upon the yield of the cotton; the actual cash return per acre is also larger.

On the other hand, with the supplies of cattle manure available, it is likely to prove impossible to cultivate continuously an area sufficient to support the population, as yields fall off after a few years. Some system of resting the land under grass must be included; but the present native system involves the use of too large an area per head of population, and we have to design a system whereby the cultivation-period of each plot can be extended, while at the same time the final residual fertility is kept at a maximum, so that the rest-period can be shortened. Experiments are in progress on the Indore method of producing compost and various modifications of it, with the object of providing a larger supply of rich manure; the chief drawback is the amount of labour required to transport the requisite large quantities of grass and water. There appears to be little hope for many years to come that the native will adopt this means of increasing his supply of manure.

(*Received August 31, 1935*)

THE INTRODUCTION OF MIXED FARMING IN NORTHERN NIGERIA

O. T. FAULKNER AND J. R. MACKIE

IN the general experience of Colonial agricultural departments it has been comparatively easy to induce native farmers to grow a new and profitable export crop or improved varieties of such crops, but it has been by no means so easy to induce them to alter their general agricultural methods. This is not because the native farmer is inherently conservative; indeed, he seems generally to be less conservative than the European farmer. The difficulty arises from the fact that, among primitive people, agricultural methods are very intimately bound up with tribal traditions, with land tenure, and with the economics of village life. Thus it often happens that what appears to the European mind to be a comparatively small change in agricultural practice involves consequences which, to the native mind, appear most formidable. There is also the further difficulty that most of the fundamental improvements which the European agriculturist can suggest to the native farmer necessitate the investment of a certain amount of capital. Judged by our standards, the sum required may be very small, but even £5 is far more than the average native peasant in Nigeria can produce.

During the last year or two the introduction in Northern Nigeria of a system of mixed farming *cum* animal husbandry has progressed at a rate that is already remarkable, and that continues to increase every year. This new system represents an improvement of the first magnitude, and involves a revolutionary change in the farmer's whole outlook upon his life and business. It may therefore be of interest to discuss the difficulties we have encountered and the methods by which we have overcome them.

In countries where there are both European and native farmers, experience has shown that the Europeans' example has influenced the improvement of the native farming. But there are no European farmers in Northern Nigeria (the cotton-seed farm belonging to the Empire Cotton-Growing Corporation is the only exception to this statement), so that the only agency through which the new system could be introduced was the Agricultural Department of the Nigerian Government, working in close co-operation with the various Native Administrations. The Government has, therefore, had to provide for the necessary research and field-experimental work, to devise a means of getting into direct touch with individual farmers, and to provide loans to enable the farmers to meet the initial outlay on cattle and implements.

An account of the climate of Northern Nigeria and the existing agricultural methods has been given by the authors elsewhere.[1] For the purpose of this article it is sufficient to mention that, before the introduction of mixed farming, all cultivation was carried out by hand, and various types of hand-hoe were the only agricultural implements used.

[1] *West African Agriculture*, by O. T. Faulkner and J. R. Mackie.

There were some three million head of cattle (of the Zebu type) in the country, but these were kept almost entirely under nomadic conditions by Fulani herdsmen, who did practically no cultivation. The cultivator as a rule owned no cattle, though he appreciated the value of their manure, and obtained it by paying Fulani herdsmen to 'kraal' (herd) their cattle on his fields at night during the dry season. It must be admitted that, wasteful as this system is, it achieved amazing results, as is shown by the annual export from Nigeria of some 200,000 tons of ground-nuts and some 20,000 tons of cotton, in addition to the production of all the corn and other foodstuffs for the whole population. In thickly populated areas, such as those surrounding the big towns, the land was maintained in permanent cultivation at a high level of fertility by frequent manuring. Elsewhere a much lower level was maintained by a combination of manuring and shifting cultivation.

When the Agricultural Department began its investigations it seemed fairly clear that a really important and great improvement would be effected if, by some means or other, animal husbandry and cultivation could be combined. There seemed scope for the introduction of animal-drawn implements; for more intensive crop production by the better conservation of manure; and also for the increased production of milk. It was realized from the outset that the introduction of ploughing alone would be a retrogressive rather than a progressive step: for by providing for the cultivation of an increased area, ploughing, by itself, would aggravate, rather than alleviate, the problem of shifting cultivation. It was clear, therefore, that the provision of a much greater supply of manure must go hand-in-hand with the introduction of ploughing. Further, it was necessary to provide suitable implements, the cost of which would be within the means of the peasant farmer; and also to find out whether the local cattle could be trained for farm work, and whether, when trained, they would stand up to such work. It was evident, too, that any improvement of the local cattle, whether for milk, work, or beef, depended on providing them with adequate food during the dry season, and that this condition could only be satisfied if the cattle were kept on their owners' farms, instead of being collected into large herds and sent off in the charge of Fulani herdsmen. The question of feeding during the dry season was therefore another problem which had to be faced.

The previous history of ploughing with cattle in Nigeria was not encouraging, for several previous attempts to introduce it, including one made by the Agricultural Department itself, had all failed. These previous attempts emphasized the necessity for preliminary experimental work. The main reason for the failure of one attempt was the use of a type of plough which was quite unsuitable for the country. Another attempt had failed because the cattle suffered too much from Trypanosomiasis; and a third because the cultural methods used were not suited to the local climate. At the outset, therefore, of our renewed effort, the agricultural officers, plant-breeders, and chemists were constituted into a team of experimenters with instructions to investigate every aspect of the subject. Their objective was to evolve a system of which every detail had been tested and re-tested in field trials and experiments. Subse-

quent events have proved the wisdom of this procedure; and it is also found that the greater the progress we make in our extension work, the more important the experimental work becomes. For now that we have gained the confidence of the farmers, we can less than ever afford to give any advice, by precept or example, which is not based on accurate and certain knowledge.

The preliminary experimental work occupied some six years, and during this period no attempt was made to induce even one native farmer to adopt our methods. The results of the main experiments are given in the Annual Bulletins of the Department, and they show that every detail which could possibly have any important bearing on the problem was fully investigated. At the end of this period we had reached the stage of having evolved a suitable cheap wooden plough, and had satisfied ourselves that the cattle were suitable for work, were easily trained, and would stand up to work. We had also carried out many experiments to ascertain the best method of making and utilizing manure, and we were satisfied that the manure from one pair of working animals, properly conserved and applied, would serve to keep some 10 acres of land at a reasonable level of fertility. It was not a very high level, but it was one which is very much higher than that of the ordinary hand-hoed farms, even of those that receive occasional 'kraaling' by Fulani herds. As soon as it seemed certain that the system was thoroughly practical and sound, we made an effort to induce three farmers to give it a trial; so that we might next learn whether our system, which seemed so sound to us, could really be adopted by an ordinary farmer, or whether it would need modification before it could be acceptable to him. During this time the Veterinary Department had perfected its system of immunizing cattle against rinderpest. This work has contributed largely to the success of mixed farming; without it we should have been in the position of asking farmers to invest their money in cattle, with the knowledge that they were almost certain, sooner or later, to lose them from that disease.

We realized at a very early stage that very few farmers, if any, could provide the capital to purchase the cattle and implements, and to stump their land sufficiently well to enable the implements to be successfully used. So, before serious extension work could be started, it was necessary to devise a scheme by which the farmer could obtain a loan at a moderate rate of interest and repayable over a period of years. To overcome this difficulty very small sums, sufficient for a few men only, were provided by the Native Administrations as an experiment. This small experiment has since been developed, and loans are now offered by the Native Administrations to any approved applicant who wishes to start mixed farming. The Native Administration organization is also used as the medium through which both capital and interest are repaid; and although the number of loans issued each year has steadily increased, until the total amount of money involved is now considerable, the system works satisfactorily and instalments are repaid with commendable regularity. The success of the system depends upon keeping the loans as small as possible, in order that they can be easily repaid in 3 or 4 years. Every

effort is therefore made to keep each loan down to a sum not exceeding £5. This sum provides a pair of working bullocks, a locally made plough, and a simple cultivator. Under the system which has been adopted, the loan, together with interest, is repaid in four instalments; and the farmer also pays 5*s.* in cash before he receives his cattle and implements. The arrangement is illustrated by the table given below:

	Capital repayment	*Interest*	*Total*
	£ *s.* *d.*	*s.* *d.*	£ *s.* *d.*
Cash	5 0	About 4 9	About 1 4 9
At the end of the 1st year	15 0		
At the end of the 2nd year	1 5 0	„ 4 0	„ 1 9 0
At the end of the 3rd year	1 10 0	„ 2 3	„ 1 12 3
At the end of the 4th year	1 5 0	„ 1 3	„ 1 6 3
	£5 0 0	„ 12 3	„ £5 12 3

The Native Administrations, in order to assist the scheme, have set aside the money they receive as interest to form an insurance fund, which can be drawn upon to replace unavoidable losses of cattle. Minor difficulties have occurred from time to time, and various adjustments have been necessary; but the system is proving to be a sound investment for the Native Administrations, and it is not unlikely that the provision of advances will become one of their permanent functions. Already the system is being extended to include the purchase of cows and of imported ploughs by those farmers who have repaid their initial loans. It cannot be too strongly stressed that in countries like Nigeria, where peasant agriculture predominates, the provision of these small loans at a reasonable rate of interest is essential to any considerable advance in agricultural methods. The working of such a scheme of loans necessitates the very close co-operation of administrative officers; and they should be regarded, and should regard themselves, as an essential part of the team of workers by whom the improvement is to be effected.

The first three farmers met with varied degrees of success, and one failed entirely; but the experience gained with these men enabled us to rectify one or two minor weaknesses of the system which we had worked out; and it also convinced us that, given a suitable method of getting into touch with them, our system would be adopted by many farmers.

Up to this stage, our work had been mainly confined to our few big experimental farms. These farms are of necessity run on European lines. The very nature of the experimental work entails the presence of several European officers, the laying out of the farms in plots and straight rows, clean weeding, full stands of plants, and so on. Experience has shown that the ordinary farmer is not much influenced by what he sees on such farms. He merely regards them as the farms of the Europeans, tends to avoid them, and takes little interest in the work that is being done on them. The big, highly organized experimental farm is therefore of very limited value as a medium for introducing improved methods in such a country as Nigeria.

In order to get into closer touch with the farmer it seemed essential that we should make every effort to work through his own Native Administration, and that we should try to demonstrate our system as nearly as possible under his own conditions. This object has been achieved by a system of farm centres and demonstration farms, financed and staffed by the Native Administrations under the advice and supervision of Agricultural Officers. This system has proved so successful in enabling us to get into touch with the individual farmer that we have adopted it as the basis of all our extension work.

The essential feature of the demonstration farm is that it shall resemble a native farm as closely as possible, and that it shall be operated by a labourer working and living under the same conditions as the local farmers. Our demonstration farms each consist of from 10 to 15 acres, which we have found to be the maximum area that can be well cultivated and manured by one ordinary farmer owning a pair of bullocks and possibly a cow and some small stock. The buildings consist of merely a house for the labourer and a pen for the cattle, both built of exactly the same materials and in the same style as the houses of the local farmers. The labourer is a man who has been trained by us, but who is, if possible, a local man; and provided that he farms well, on the lines laid down by the Department, he is given a free hand and receives a minimum of supervision from European officers. We have found that it is best to pay the labourer a definite wage and to sell all the saleable produce available from the farm. An alternative system by which the labourer receives no wage, or a very small one, but receives the produce, was tried but proved unsatisfactory. Under that arrangement we had not sufficient control of the working of the farm. For a man working on that system cannot, in fairness, be removed in the middle of the cropping season. Yet it is essential that every detail of the system should be properly demonstrated, for it is attention to every detail that ensures success. Thus it is important that the cattle should receive sufficient bedding, that all waste products of the farm should be conserved, and that the implements should be used to the fullest extent. In such matters the unpaid labourer is apt to be slack; the paid labourer can be kept up to the mark or be replaced by another.

Only practices which have been proved by experiment to be absolutely sound in every way are demonstrated on the demonstration farms, no experiments of any sort are carried out on them; but the system demonstrated does not remain entirely stable from year to year, for every advance in our knowledge, as obtained from our experiments, is incorporated at once in the system which is demonstrated on these farms. All farmers have free access to the demonstration farms and are encouraged to visit them as often as possible. They can receive instruction and advice from the labourer in charge, and can also send their boys to the farms for practical instruction in the use of implements or the management of cattle.

The farm centre differs only from the demonstration farm in that it is on a bigger scale and provision is made for carrying out minor experiments under local conditions. For example, if the Botanist obtains an

improved strain of cotton on the main experimental farm, it is again tested at the farm centres before being given out to the demonstration farms. This is an important function of the farm centres, for Northern Nigeria is a vast area comprising a wide diversity of climatic and soil conditions, and the number of main experimental farms which the Government can afford to maintain is, owing to their cost, obviously limited. Yet it is unlikely that improved strains or methods evolved at one or two places will be suitable for the whole of the Northern Provinces. The farm centres give opportunity for tests in many localities; they, like the demonstration farms, are also increasingly used as training centres for both boys and cattle; sick cattle are brought to them for treatment; and there is also a blacksmith's shop where implements are made and repaired. Both farm centres and demonstration farms are cheap to establish and to maintain, and every effort is made to ensure that, as a result of good farming, they are self-supporting, i.e. that the cost of working them is offset by the value of the crops produced.

The value or otherwise of small demonstration farms is a point which has often been debated by officers of agricultural departments, and opinions about this subject have differed widely. The conclusion which we have reached in Northern Nigeria is that such farms are an invaluable method of disseminating results to individual farmers. Demonstration farms are, however, only a success if they are really necessary, that is, if there is something of value to demonstrate which cannot be demonstrated otherwise. Such a farm will not be a success if its object is vaguely to demonstrate general good farming, nor if it merely introduces a new variety of seed, which could just as well be demonstrated on farmers' own fields. Our experience has shown that the farms are essential for the introduction of such a system as that of mixed farming, and as we are only just at the beginning of the problems connected with animal husbandry in Northern Nigeria, it is probable that we shall have something of real value to demonstrate for many years to come. If we ever reach the stage when we have nothing new and important to demonstrate, then the demonstration farms will be closed down; for when that stage is reached the farmers who have already adopted our system successfully will provide a better demonstration than anything we could provide.

Up to the present we have had to concentrate our main efforts on getting farmers started; for the purchase and training of the bullocks, and the manufacture of the implements in sufficient numbers are tasks of some magnitude. During the present season some 300 applicants were 'set up', and probably twice that number will be started next year. The necessary organization for dealing with much greater numbers is gradually being evolved.

The ordinary farmer normally cultivates only about 3 or 4 acres, and he cannot clean and stump some 6 or 7 extra acres all at once. He does so gradually, and it takes him about three years to increase the size of his farm and obtain the maximum production from it. In the meantime he learns the value of providing his cattle with an adequate supply of bedding in order to obtain the maximum quantity of manure; he learns also that his cattle must be well fed, and how to provide the food most

economically; he also learns that they must receive prompt attention as soon as they show the very first signs of ill health. The next step is to induce him to keep a cow, for the produce of one good cow will bring him in a greater net income than 2 or 3 acres of land when produce prices are at a normal level. Several farmers have already obtained cows, and the demand increases every year. As milk is such a valuable commodity it was clearly worth while to make an attempt to improve the performance of the local cows, and a stock farm for the improvement of cows was an obvious corollary to the introduction of mixed farming.

The improvement of live stock cannot be achieved quickly: it takes several years from the commencement of such a scheme to the time when the improved animals can be placed in the hands of the ordinary farmer. This was realized by the Nigerian Government at a very early stage, and a stock farm was established very soon after the experimental work on mixed farming was begun. Consequently, by the time when a considerable demand for improved cows will arise, we hope to be in a position to supply them, at least in limited numbers; and also to have bulls of heavy-milking strains available in adequate numbers, so that every farmer shall be able to take his cows to an improved bull.

Our work at the stock farm is confined to an attempt to improve the local cattle by selective breeding, and we have resisted the temptation to try to achieve quick results by introducing improved breeds from other countries. There are several well-defined types of cattle in Nigeria and we are at present working on four of them. Under the nomadic conditions in which the cattle are normally kept by the Fulani herdsmen, very little improvement is possible; but even under such conditions there are some strains with inherent milking-quality. When these animals are kept on the farm and are well fed throughout the year their milk-yield improves immediately. Selective breeding in itself therefore offers no serious difficulties, and progress in this direction has been more rapid than might have been anticipated. The main problem connected with this work has been that of feeding. We were quickly able to demonstrate that if a farmer conserves all the waste products of his farm, such as the leaves of his guinea-corn crop, his guinea-corn bran, and the leaves and stems of his ground-nut crop, he will have an adequate supply of food for his working beasts; but the provision of a suitable ration for high-yielding cows throughout the long dry season was a much more difficult problem. Although we are not yet satisfied that everything possible has been tried, we have been able to work out a suitable ration of foodstuffs grown on the farm that meets our present needs. This ration is based on using a leguminous crop for hay and sweet potatoes as a succulent fodder crop. Both roots and vines of this crop are readily eaten by the cattle and are most nutritious, and the yield per acre is very satisfactory. The farmer will naturally not wish to devote more of his land to the growing of fodder crops than is absolutely necessary, so we are still trying to find more quickly growing and heavier-yielding fodder crops than those which we have at present.

The introduction of mixed farming on the lines indicated above is a revolutionary change in native agricultural methods, and its full effects

on the country cannot yet be foreseen. Many problems still remain to be solved; but the progress made up to the present is most encouraging. A means has been found by which the results of research and experiments can be brought to the notice of every farmer, and it is certain that both specialist officers and agricultural officers have a programme of useful work before them which will keep them fully occupied for a period of many years.

(*Received October 7, 1935*)